SCIENTIFIC AGRICULTURE

Volume 23 FEBRUARY, 1943 No. 5

SEED SETTING IN ALFALFA III[1]

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[Received for publication July 10, 1942]

This paper is the third in a series dealing with factors affecting alfalfa seed production. The phases of work reported upon here are:

1. The effect of hand tripping and application of foreign pollen as against hand tripping and selfing.
2. The effect of caging plants with bumblebees.
3. The effect of mutilation of flowers.
4. The effect of mechanical tripping.

REVIEW OF PREVIOUS WORK

A fairly comprehensive review of the literature pertaining to the subject has been presented in the first two papers of this series. The following are repeated or added because of their special relation to the findings reported here.

Frandsen (3) obtained a ratio of 1 : 1.8 for pod setting in favour of hand tripping and cross-pollinating flowers over hand tripping and selfing, and an increase of 246% in number of seeds per pod when the flowers were cross-pollinated. This was supported by Piper and others (4), who found that 46.1% of flowers set pods when pollinated with foreign pollen as against 32.1% when selfed, and obtained a ratio of 2.38 : 1.4 in number of seeds per pod in favour of cross-pollination.

Lejeune and Olson (1) found bumblebees close to 100% effective in tripping flowers.

Silversides and Olson (2), in studying the effect of various types of flower mutilation, found that the treatments which reduced seed setting more or less sharply were, removal of the standard before or immediately after tripping, cutting off the standard immediately below point of contact with the stigma, and severe squeezing of the racemes. Armstrong and White (5) found conclusive evidence to prove that the rupture of the stigmatic surface is essential for pollen germination and fertilization and that tripping of the flower will more than likely rupture the stigmatic surface.

So far as known, no literature is available relating to the effect of the alfalfa plant bug *Adelphocoris lineolatus* Goeze. on seed setting. This insect was found to be widespread in Manitoba this year and is suspected of being partly responsible for a general failure in seed setting. A great deal of bud blasting, blossom drop, and shrivelled seed was evident, very similar in description to the Lygus bug damage reported by Sorenson (6).

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THE EFFECT OF HAND TRIPPING ACCOMPANIED BY APPLICATION OF FOREIGN POLLEN AS AGAINST HAND TRIPPING AND SELFING

This experiment was performed in triplicate, with both treatments on the same plant. Each replicate consisted of one plant, separated above the ground into two portions by separately enclosing each half of the plant in a wire screen cage to exclude insects. The flowers on 50 racemes on one of the portions were tripped and selfed, and on the other portion, tripped and foreign pollen applied by tapping the stigmas with dehiscing anthers taken from flowers on other plants of the same variety. All the racemes worked with were tagged, and the number of flowers on each, recorded on the tag. When mature, the racemes were harvested and the number of pods per raceme and number of seeds per pod recorded. The data are presented in Table 1.

TABLE 1.—EFFECT OF CROSS-POLLINATION VS. SELFING

Treatment	No. of flowers treated	No. of pods formed	No. of seeds formed	Flowers forming pods	Seed set (flower treated basis)	Average no. of seeds per pod
				%	%	
Hand tripped, foreign pollen	2,114	456	238	21.6	11.3	0.54
Hand-tripped, selfed	2,122	291	57	13.7	2.7	0.17

The ratio for pod setting was 1 : 1.6 in favour of cross-pollination. There was an increase of 317% in the average number of seeds per pod. The percentage of flowers setting seed was increased more than four-fold (11.3 as against 2.7).

THE EFFECT OF CAGING PLANTS WITH BUMBLEBEES

Three plants were used, each plant comprising 1 replicate. A large wire screen cage was placed over each and the plant was then divided, above the ground, into two portions. One portion was enclosed in a smaller cage as a check, and the other left accessible to bumblebees which were released in the large cage. About 100 racemes on each portion were tagged and the number of flowers on each recorded on the tag. All tripped and very immature flowers were removed.

A number of bees were collected, chiefly in the vicinity of raspberry bushes, and about six released in each large cage. Two or three more were added to each cage a little later. Bees were present in the cages at all times while the tagged racemes were in bloom.

When mature, the tagged racemes were harvested and the number of pods per raceme, and number of seeds per pod, recorded. Table 2 gives the averages of the data for two replicates. The data for replicate 1 were discarded because one bee gained access to the portion of the plant used as the check. Seed setting here was considerably higher than for the checks in the other two replicates.

TABLE 2.—EFFECT OF CAGING PLANTS WITH BUMBLEBEES

Treatment	No. of flowers treated	No. of pods formed	No. of seeds formed	Flowers forming pods	Seed set (flower treated basis)	Average no. of seeds per pod
				%	%	
Caged with bees	1,145	387	215	33.8	18.8	0.38
Caged without bees	1,205	53	43	4.4	3.6	0.58

A marked increase for caging with bees is apparent on percentage flower-treated basis. The average number of seeds per pod is small, being less than 1 in both cases and the difference of 0.2 between them is of doubtful significance.

Brief mention of the conduct of the bees within the cages, may be of interest. Although the cages were under frequent observation, more than 1 or 2 bees in a cage were never seen to be visiting flowers at any one time. The others were either on the ground or were attempting to escape. Of the flowers that were observed while bees were visiting them a high percentage were found to be tripped.

THE EFFECT OF MUTILATION OF FLOWERS

As described in the previous paper, Silversides and Olson (2), various types of mutilation were performed on flowers to note the effect on seed setting and to learn, if possible, what types of damage were most destructive.

Eight different treatments were applied to each plant and 5 plants were used for each treatment, making 5 replications. Ten racemes were used for each treatment in each replicate. The data are presented in Table 3.

The figures in brackets were obtained by rating the treatments from 1 to 8 (lowest to highest value) for each of the four criteria, namely percentage flowers forming pods, percentage pods forming seed, percentage flowers setting seed, and number of seeds per pod. The average treatment rating, shown in the last column, is the average of the four ratings for each treatment.

The outstanding features of the data are the high values for the treatment whereby the keel was pinched until tripping took place (item 2) and the low values where the keel was tripped after cutting off standard (item 8). The former evidently provided the most favourable conditions for seed setting among all the treatments applied. The high rating is consistent for all of the criteria. The latter, on the other hand, was the treatment that did the greatest damage or provided the least favourable conditions for seed setting. Both of these results may be said to be in agreement with expectation. Tripping, which is a prerequisite for fertilization, was evidently accomplished with a minimum of damage to the flowers by the first-named treatment. With regard to the second, it removed the means of rupturing the stigmatic surface, which, according to Armstrong and White (5), is necessary to render it receptive to pollen, or to provide

for pollen germination, and is usually accomplished when the stigma strikes against the standard in the normal process of tripping. Both of these results are in agreement with those reported for the same treatments in the earlier paper by Silversides and Olson (2).

Conspicuously poor results as regards seed setting were also obtained where the standard was cut off after tripping the keel (item 3). It must be noted that it was found difficult to accomplish this treatment with the instruments used (scissors and tweezers) without injuring the staminal column. In the previous paper by Silversides and Olson (2) considerable damage was reported from this treatment.

Severe squeezing of the flowers appeared to do considerable damage in one case (item 6) where the squeezing was done after tripping the flowers and comparatively little or at most moderate damage in the other (item 7) where it was done without first tripping the keel. There seems to be no plausible reason why there should be a difference between these two treatments. Mechanical injury might be expected if the squeezing were severe enough. To gauge or satisfactorily control the severity of the squeezing might well be a disturbing factor here. Both of these treatments seemed to do considerable damage in the preceding study.

TABLE 3.—EFFECT OF FLOWER MUTILATION ON SEED SETTING

Treatment	No. of flowers treated	No. of pods formed	No. of seeds formed	Flowers forming pods	Pods forming seed	Average no. seeds per pod	Average treatment rating
				%	%		
1. Corolla and keel squeezed until tripping took place	639	178	123	27.9 (3)	42.1 (7)	0.56 (7)	5.7
2. Keel pinched until tripping took place	648	255	174	39.3 (7)	43.5 (8)	0.65 (8)	7.7
3. Standard cut off after tripping keel	611	147	52	24.1 (2)	25.9 (4)	0.33 (3)	3.0
4. Keel tripped, then standard cut off above point of contact with stigma	617	213	101	34.5 (6)	35.7 (6)	0.45 (5)	5.7
5. Keel tripped then keel cut off	599	239	79	39.9 (8)	21.8 (2)	0.32 (2)	4.0
6. Flowers tripped, then racemes squeezed severely between fingers	620	197	72	31.8 (4)	24.9 (3)	0.43 (4)	3.7
7. Racemes squeezed severely without first tripping flowers individually	621	208	99	33.6 (5)	35.6 (5)	0.55 (6)	5.3
8. Keel tripped after cutting off standard	490	105	21	21.4 (1)	13.4 (1)	0.14 (1)	1.0

Cutting off the standard above the point of contact with the staminal column after tripping seemed to offer comparatively little interference with seed setting. This again is in agreement with the earlier results.

Squeezing individual flowers until tripping took place (item 1) while it showed a high rating for the average of the criteria showed a surprisingly low rating for percentage of flowers forming pods. This treatment as well as that represented by item 2 appeared favourable in the earlier experiment.

Where the keel was tripped and then removed (item 5) inconsistent results were also obtained. The rating and value for percentage flowers forming pods is very high, while that for the other criteria is low to medium. This treatment showed highly favourable results in the earlier investigation.

THE EFFECT OF MECHANICAL TRIPPING

Two mechanical tripping experiments were conducted, using a hand-made rotary tripping machine. The essential features in the construction of this machine are as follows:

Two hollow, canvas-covered, wooden rollers, about 30 inches in length and 8 inches in diameter, are vertically mounted on the rear of a corn cultivator from which the shovels have been removed. The rollers are mounted side by side, in such a way that they adjoin closely at the top, and at the base, lie normally about 2 inches apart. Springs at the basal attachment allow a further spread. One roller is geared, by a chain drive, to one wheel of the cultivator, and as the machine moves, rotates, causing the other to rotate, by friction, in the opposite direction. The machine is driven down a row (the alfalfa must be sown in rows), one wheel on either side of the row, and the alfalfa passes between the rollers, many of the racemes being squeezed in the process. Two rods attached at the front of the machine, which can be raised, lowered and moved sideways by levers, move one on each side of the row and aid in picking up overhanging stems, to ensure their passage between the rollers. The theory behind this machine is that its action will simulate that of drawing a cluster of flowers between the thumb and fingers or the palms of the hands, which is a very effective means of tripping the flowers.

One experiment was designed to test the effect on seed setting of tripping on different dates and different numbers of times over with the machine, and was of the split plot type. Each plot consisted of 2 rows, one row receiving the treatment once, and the other, weekly. Four rates of treatment were used, namely,

1 way once—1 way weekly
2 ways once—2 ways weekly
3 ways once—3 ways weekly
4 ways once—4 ways weekly

The treatments were replicated four times, and one row was left untreated in each replicate as a check. Three weekly treatments were given, the second one aimed to catch the alfalfa at or near the stage of maximum blossoming. The rows receiving the treatments only once were treated at that stage.

Unfortunately, blasting of buds and flowers so reduced the amount of seed set that no yields were obtained from either of the tests. However,

tripping counts were made to measure the tripping efficiency of the machine. Immediately before treating each replicate, 50 racemes taken at random over the length of the check row were examined, and the total number of flowers and number tripped on each, recorded. Similar data were recorded for each plot after treatment. The tripping results are shown in Table 4. These data are the counts made after the first weekly treatment.

TABLE 4.—TRIPPING EFFIENCY OF ROTARY MACHINE FOR DIFFERENT RATES OF TREATMENT

Treatment	No. of flowers counted	No. of flowers tripped	Percentage tripping
			%
Check	3,937	432	11.0
1 way	3,734	774	20.7
2 ways	3,413	1,124	32.9
3 ways	3,489	1,757	50.4
4 ways	3,288	1,760	53.5
	Necessary difference 8.0%		

It is evident from the data that the percentage tripping for each increased rate of treatment was significantly higher than for the previous, up to 3 ways, at which rate 50% of the flowers were tripped. Wilted flowers were counted as tripped.

Increasing numbers of times over with the machine caused increasing injury to the plants. Seed yields, had they been obtained, would probably have indicated whether the percentage tripping with increased numbers of times over, would more than offset the greater injury to the plants. From the data in Table 4, it is doubtful if treating more than 3 ways would be justified.

The second experiment was designed to test the effect on seed setting of using different materials to cover the rollers on the machine, in the hope that a material could be obtained which would collect and distribute pollen in the process of tripping, and thus bring about some cross-pollination. The materials tested were:

1. Canvas (standard cover as used in previous test).
2. A fairly stiff, short-piled rug.
3. A soft mohair cloth with a fairly long pile.

The test was in 4 replicates, with two row plots for each treatment, and one check plot in each replicate. The machine was driven up and back each row (2 ways), and the treatments were made at the stage of maximum blossoming. Tripping counts were made, in the manner previously described, except that wilted flowers were excluded from the counts. The tripping data are presented in Table 5.

TABLE 5.—TRIPPING EFFICIENCY OF ROTARY MACHINE FOR DIFFERENT ROLLER COVERINGS

Treatment	No. of flowers counted	No. of flowers tripped	Percentage tripping
			%
Check	2,011	30	1.49
Canvas	1,932	646	33.4
Short-piled rug	1,822	742	40.7
Mohair	1,887	471	25.0

Necessary difference 10.0%

A significant difference in percentage tripping is noted for the short-piled rug over the mohair. Without seed yields, no basis is available on which to judge whether any cross-pollination was obtained. An indication of this might be given by correlating seed yield with tripping data.

It will be noted that the percentage tripping for the check is much lower than the corresponding figure in Table 4. This difference may be accounted for by the fact that the Table 4 count includes the wilted flowers.

SUMMARY

1. Cross-pollination of artificially tripped flowers markedly increased seed setting.

2. Plants caged with bumblebees set a considerably higher percentage of pods and seeds. Of the flowers visited by the bees, a high percentage were seen to be tripped.

3. Various kinds of mutilation of flowers were performed. The treatments most injurious to seed setting were removal of the standard before, and immediately after tripping, and severe squeezing of the racemes after first tripping the flowers individually.

4. Mechanical tripping with a home-made rotary machine was highly successful from the standpoint of flowers tripped, 50% of the flowers being tripped in a 3 way application. The effect on seed setting was not determined due to an unexplained blossom drop and bud blasting, which prevented the setting of any appreciable amount of seed. This condition was general for the district and not attributable to the treatment with the machine. Different materials used as coverings for the rollers on the machine, varied in the percentage tripping achieved. A fairly stiff, short-piled rug gave a significantly higher percentage tripping than mohair.

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TOMATO VARIETAL YIELD TESTS[1]

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Great strides have recently been made in the development and introduction of new tomato varietal types for the Prairie Provinces. Until recently the chief kinds available have been selections from the indeterminate type which is grown in the East. Alberta, with its short season and cool nights, is possibly more exacting than Manitoba or Saskatchewan in its requirements of early varieties. With the intention of testing varieties for selection of those most suitable to Alberta conditions, a test plot (1) of a large number of varieties was established at the Station in 1937 and has been continued each year since then. Besides the test plot, breeding work has been conducted with the tomato and selection of types practised. During the 1938 season a co-operative test was carried on with the Department of Horticulture, North Dakota Experiment Station, Fargo, North Dakota.

PROCEDURE

The plants used were comparable to those available to the home gardener or to the commercial producer of tomatoes, and representative of those raised by growers in good manure-heated hotbeds. The plants were not allowed to become large or leggy before planting. In 1937 the seeds were sown April 9-14 and in 1938, 1939, and 1941 seeding was advanced to March 16-21. The plants were set in the field as soon as the weather was sufficiently settled and danger of a late frost was past. The dates for each of the years was as follows: May 25, May 28, May 30, and June 2. No staking or pruning was practised. Cultivation was reduced to a minimum and was only resorted to for the control of weeds and to prevent baking after irrigation. During the four years of the test the following number of varieties, included in the test, was 19, 31, 35, and 22, respectively. The number of plants set and the number of replicates varied with the area available for planting and the facilities for growing the plants. This information is available in Table 1.

Notes were kept each year of the vigour and growth, blossom period, type and quality of fruit, and habits of the plants. Picking was started when the first ripe fruits appeared. The yields are summarized in Table 1 for pickings of ripe fruit for all years and pickings of green and ripe fruit for the years 1937, 1938, and 1939.

Eight tomato varieties were grown in a co-operative test with the Horticultural Department of the North Dakota Agricultural Experiment Station. The plants were planted in the form of a latin square in both tests and similar records kept for comparative purposes as to yields and reaction to the different environments. The seed used for both tests was from the same source.

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[1] Paper read at the Horticultural Group meetings of the Canadian Society of Technical Agriculturists at the Annual Meeting at Olds, Alberta, June 18-19, 1942.

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TABLE 1.—YIELDS OF TOMATO PLOTS 1937-1941 IN POUNDS PER PLANT

Variety	1937			1938			1939			1941	
	Ripe		Green and ripe	Ripe		Green and ripe	Ripe		Green and ripe	Ripe	
	Sept. 10	Sept. 22	Sept. 22	Sept 10	Sept. 24	Sept. 24	Sept. 13	Sept. 20	Sept. 20	Aug. 22	Sept. 6
	15 var.	4 reps	5 per rep.	31 var.	4 rep.	4 per rep.	35 var.	2 rep.	8 per rep.	2 rep.	10 per rep.
Abb 0-4208				6.6	15.1	26.3					
Abel				9.8[2]	17.3	21.9	0.87	1.1	13.4		
Abel X Farthest North F4 (Leth)										1.3[6]	6.0
Ailsa Craig	0.5	3.3	28.8	2.7	8.8	28.4					
Alacrity							0.6	1.5	19.7		
Allred or N.D. 216-2-3				7.3[6]	12.6	15.4	3.2[2]	4.9	13.3	1.0	8.5[4]
Bestal				4.0	12.2	—					
Best of All							0.4	0.6	16.7		
Bison (N.D.)	4.6	11.1	18.1	1.9	6.4	8.6	2.9[6]	6.1	18.7		
Bison (cert)										0.5	7.8[6]
Bison (B.S.)	6.5[2]	11.7	17.0	11.8[1]	13.2	20.7	3.0[5]	5.0	17.2		
Bonnybest	1.1	4.4	27.4	2.8	10.5	28.6					
Bounty (McFayden)										0.3	3.0
Bounty (Morden)										1.6[3]	9.3[3]
Bounty (Sel. Fargo)										0.4	3.3
Break O'Day							0.4	0.5	17.9		
B.V.A.1										1.5[4]	9.3[2]
B.V.A.2 Bison Selections										0.5	4.3
B.V.A.3										1.2	10.2[1]
B.V.4										1.3[5]	6.9
B.V.5 Station Hybrids										3.9[1]	8.1[5]
B.V.6										2.0[2]	5.9
Brown's Own	0.25	1.6	29.3	2.4	9.0	24.8					
Burbank	1.0	4.5	27.0	2.2	7.5	20.5	0.5	1.0	23.4	0.1	0.3
Cardinal							0	0.2	13.5		
Clarke's Early										0.4	0.37
Colossal							0	0	8.1		
Denmark				2.2	8.6	22.4					
Drought Resistant							3.2[4]	4.1	14.7		
Earliana	0.6	3.1	19.1	3.2	7.2	27.3	0.4	0.5	11.8	0.1	1.9
Fargo Yellow Pear	2.2	5.8	23.1	2.9	7.5	12.5					
Farthest North	1.6	3.8	3.8	2.4	2.8	—	2.3	3.3	4.1		
Feonea							0.7	0.9	15.1		
First of All							0.4	1.4	23.9		
Fletcher's Special							0.4	0.7	9.6		
Globonnie				2.7	9.3	27.8					
Golden Bison	3.9[5]	10.6	22.1	2.4	9.0	16.1					
Harkness				5.6	14.4	25.6	0.5	0.9	14.4		
John Baer	1.1	4.8	29.3	2.8	12.1	37.1					
Jumbo	0.7	3.2	22.9								
Mingold							0.5	1.4	13.4	0.5	4.3
Michigan 4137							1.5	3.9	15.2		
New York Seedless										0	0.1
N.D.A.C. (SPT)							2.2	3.2	11.7		
N.D. 38							1.1	2.4	18.4	1.0	7.2
N.D. 40 lot 39-7										0.5	4.1
N.D. 209-2-10	4.8[3]	13.6	24.1	7.8[5]	11.4	13.7	1.0	4.9	19.6		
N.D. 215-P-2	3.7[6]	13.1	25.1	5.5	15.0	18.9					
N.D. 216-2-3 or Allred	7.3[1]	14.2	19.4								
N.D.A.C. 303										0.5	5.5
N.D. 500				4.4	9.2	10.5	1.5	2.6	12.7		
Nystate				1.5	6.3	13.1					
Orwald	2.8	2.2	3.3								
Orwald 158				0	1.4	10.4	0.3	1.2	17.3		
Orwald 157				0	1.1	10.0					

TABLE 1.—YIELDS OF TOMATO PLOTS 1937-1941 IN POUNDS PER PLANT—*Concluded*

Variety	1937			1938			1939			1941	
	Ripe		Green and ripe	Ripe		Green and ripe	Ripe		Green and ripe	Ripe	
	Sept. 10	Sept. 22	Sept. 22	Sept. 10	Sept. 24	Sept. 24	Sept. 13	Sept. 20	Sept. 20	Aug. 22	Sept. 6
	15 var.	4 reps.	5 per rep.	31 var.	4 rep.	4 per rep.	35 var.	2 rep.	8 per rep.	2 rep.	10 per rep.
Oxheart							0	0	9.5		
Penn State							0.6	1.4	17.0		
Pepper Diener							0	1.7	8.7		
Polar Circle				6.0	15.0	22.8	1.6	3.1	20.9		
Ponderosa	0.9	3.1	23.2								
Princess Mary	3.0	9.2	28.2	9.5	16.2	23.7	1.0	2.9	17.7	0.2	3.0
Pritchard							0.6	1.1	13.7		
Prosperity				2.6	8.1	16.1					
Red River	4.1[4]	10.5	33.3	8.8[4]	15.6	24.9	0.5	1.4	21.9		
Red Skin							3.2[1]	5.2	12.5		
Selection 16-37							3.2[3]	4.6	15.0		
Selection 18-37				7.0	14.8	24.5					
Summerset										0.3	2.0
Sunrise							0.4	0.6	11.1		
Ventura							0.4	1.0	20.8		
Vernon				4.6	14.1	30.2					

NOTE.—1-6 Placing of varieties in respective years.

RESULTS

General Test

The yields of fruits and comparable dates are set forth in Table 1 for the general test and in Table 3 for the co-operative test. Yields of ripe tomatoes are seldom obtained after September 10 in Alberta and varieties that will give a high marketable yield of ripe fruit by this time are necessary to successful tomato production. Pickings up to this date, at Brooks, are the most important as a basis of varietal selection.

TABLE 2.—FIRST SIX VARIETIES IN YEARLY TESTS

Placing	Sept. 10/37	Sept. 10/38	Sept. 13/39	Aug. 22/41	Sept. 6/41
1	N.D. 216-2-3 (Allred)	Bison B.S.	Red Skin	B.V.5	B.V.A3
2	Bison (B.S.)	Abel	Allred	B.V.6	B.V.A1
3	N.D. 209-2-10	Princess Mary	Sel. 16-37	Bounty (M)	Bounty (M)
4	Red River	Red River	Drought Resistant	B.V.A1	Allred
5	Golden Bison	N.D. 209-2-10	Bison B.S.	B.V.4	B.V.5
6	N.D. 215-P-2	Allred	Bison N.D.	Abel X Farthest North F4 (Leth)	Bison (cert)

NOTE—

N.D.	North Dakota Agricultural Station.
B.S.	Brooks Seed.
Sel. 16-37	A Minnesota Introduction.
M.	Morden Selection.
Leth.	Lethbridge.
B.V.	Brooks vegetable selection.
	B.V./A1 and A3 are Bison Selections.

The six varieties that led in yield each year in the general test are shown in Table 2. Yields from later pickings were available for the 1937, 1938, and 1939 tests but because of frost on September 8, 1941, the yield of ripe fruit for that year was fixed by the picking made on September 6. It is interesting to note that the varieties Bison and Allred appeared in the first 6 high yielding varieties each year. It was only in 1938 that any indeterminate types yielded sufficiently well to be grouped here. These 2 varieties were Abel and Princess Mary. In all other cases determinate varieties were to the fore.

The varieties introduced by the North Dakota Agricultural Station have ranked high throughout the test. The variety selections out of Bison, namely, B.V.A1 and B.V.A3, have proven much earlier and more uniform than the Bison type commercially available. The variety Bounty although not quite so early as the Bison types has a better shape and is a good packer and shipper. Its colour could be improved. The two hybrids developed at Brooks as a result of crossing Farthest North and Burbank have given a very early yield of ripe fruit. B.V.5, a red selection from this cross, is a very good canner and B.V.6, a golden type, is proving very popular. Both of these selections have fruit of medium size, comparable with that of the greenhouse variety Sunrise. In the 1941 test, B.V.5 was placed in the first 6 varieties up to August 22 in its yield of ripe fruit. It yielded 3.9 pounds per plant, or 1.9 pounds more than the yield of its closest competitor which was also a selection from the same cross.

Co-operative Test

The test conducted in co-operation with the North Dakota Department of Horticulture included the following varieties: Bison, Red River, Allred and N.D.38 which were developed at that Station; Harkness, a variety of Ontario origin; Red Cap, an introduction of the New York Experiment Station; and Earliana, which was used for comparative purposes.

TABLE 3.—YIELDS OF TOMATO VARIETIES GROWN IN LATIN SQUARE TEST IN CO-OPERATION WITH NORTH DAKOTA AGRICULTURAL STATION, WITH 8 VARIETIES, 8 PLOTS TO THE VARIETY AND 4 PLANTS PER PLOT

Variety	Ripe fruit in oz. per plot of 4 plants		Total ripe and green fruit in lb. per plot to Sept. 20, 1939
	Yield to Sept. 13/39	Yield to Sept. 20/39	
	oz.	oz.	lb.
Allred	169.5	329.4	63.7
Bison N.D.	164.7	369.2	79.1
Bison B.S.	148.5	257.6	61.4
N.D. No. 38	51.5	117.9	78.2
Red River	39.1	90.5	84.6
Penn State	24.0	66.1	63.7
Earliana	17.1	26.5	67.7
Harkness	23.8	46.9	75.6
Mean	77.8	163.0	76.2
Standard Error	± 19.6	± 23.45	7.25
Significant Diff.			
For odds of 19 : 1	56.1	66.9	20.7
For odds of 99 : 1	75.0	89.5	27.6

Allred, Bison (N.D.) and Bison (B.S.) gave the greatest yields in the co-operative test (Table 3). The yields between these three varieties were not significantly different but were significantly greater than the remaining varieties. In the co-operative test Red River gave the highest yield at Fargo but stood fifth at Brooks, whereas Allred topped the yield at Brooks and stood fifth in the Dakota test. This can possibly be explained by the fact that the Allred plants in the North Dakota test were comparatively inferior to other plants (2) when set out in the field. Otherwise, the high yielding varieties placed in the same order.

CONCLUSION

The tests to date bear out the belief that in Alberta under field conditions and when pruning is not practised the newer determinate varieties will outyield the indeterminate varieties. There is still a great opportunity for the development and introduction into Alberta gardens of a variety that will produce earlier marketable yields of ripe tomatoes. Such a variety will not necessarily have the ability to give a high total yield of fruit but it should have the ability to ripen a high percentage of its fruit. The variety Farthest North is potentially such a variety but its fruit is much too small. Hybrids between it and other early large fruited types are showing promise. The variety B.V.5, the result of such a cross, should find a place in the home garden but the fruit is not large enough for commercial purposes. Bounty and smooth selections from Bison are suitable for commercial production, and are finding a ready market.

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PRACTICAL PROPAGATING RESULTS WITH NURSERY SEED STOCKS[1]

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Following the publication of "Propagating Trees and Shrubs from Seed" (1) and the results on germination tests with *Amelanchier alnifolia* and *Prunus pennsylvanica* (2) careful records have been kept in practical nursery work. Certain modifications of previous recommendations were found to be necessary with a few species.

METHODS

An arbitrary date was set for planting in the seed beds which was, at Brooks, the first week of May. The required time taken from table (in (1)) for stratifying each species was counted back from this set date to give the date at which after-ripening was to commence. The cleaned seed which had been stored dry in a root cellar was stratified and after-ripened according to the calendar of dates set. Peat moss or sand was used as a medium. If peat was used it was washed under running water before use, to remove excess acid. More general use has been made of clean sand. It drained better, removing the danger of excess moisture and avoided the danger of excess acidity. After stratifying, the seed was placed in a root cellar where the temperature was regulated between 34° and 40° F. A careful check was maintained as to moisture, particularly towards the end of the required period. A slight excess of moisture would start premature germination in many cases. The seed was sown in the seed beds, on the predetermined dates. The beds were typical nursery frames with wooden sides and lath slat covers. The soil in the beds was kept moist until germination was completed.

SEED TREATMENT RECOMMENDATIONS

The data as presented in (1) were largely the result of laboratory tests. The species, as well as many varieties within species reported have been used in practical work and the methods recommended in "Propagation of Trees and Shrubs from Seed" have been accepted or modified for the following; *Acer*, *Aesculus*, *Amelanchier*, *Amorpha*, *Ampelopsis*, *Betula*, *Caragana*, *Celastrus scandens*, *Crataegus*, *Cotoneaster*, *Corylus*, *Elaeagnus*, *Evonymus*, *Fraxinus*, *Juniperus*, *Juglans*, *Malus*, *Pinus*, *Prunus*, *Pyrus*, *Quercus*, *Sambucus*, *Shepherdia*, *Sorbus*, *Tilia*, and *Vitis*. Satisfactory results were obtained with all but a few of the species and further information can be given for others. Modifications found necessary are outlined in Table 1.

If *Aesculus* (Horse Chestnut) is stratified it tends to germinate prematurely. Greater success is obtained by burying the seed under trees, about 4 to 6 inches deep in a wire-mesh bag. Constant moisture is required. The nuts should be gathered as soon as ripe. Allowing them to be exposed

[1] Paper read at the Horticultural Group meetings of the Canadian Society of Technical Agriculturists at the Annual Meeting at Olds, Alberta, June 18–19, 1942.
[2] Assistant Superintendent.

to drying conditions lowers the viability. It is not necessary to remove the hull before burying. The same process is applicable to Walnut and Butternut.

Saskatoon seed (*Amelanchier*) gathered under varying conditions and from different strains was found to vary as to its after-ripening requirements. Some seed lots gathered at Brooks germinated in 100 days, whereas the usual time required is 200 days. Once the after-ripening process of Saskatoon seed is completed germination will commence at freezing temperatures. If germination occurs earlier than expected, the seed must be sown in flats or stocks will be lost.

Seed of *Crataegus succulenta*, the native hawthorn, gives a fair germination after 195 days of after-ripening. Further germination will occur during the following year.

Corylus (Hazelnut) seed was adversely affected when stratified in peat moss. The use of peat moss is not recommended. Good results were obtained with the use of clean sand.

Treatment to which seed of Apple and Crabapple is subjected at harvest markedly affects the time required for after-ripening to be completed. Seed from fruits that have hung on the trees late in the fall and seed from fruits removed from cold storage requires a much shorter period of after-ripening than seeds picked at the normal time, removed from the pulp, and stored dry. Seed removed from fruit that has been lying on the ground is also affected in the same way. The time required for after-ripening of normal apple seed was previously reported (1) as 60 to 85 days. After-ripening of 60 days was found to give better seedling stands when seed is gathered and cleaned at the normal time. The species *Malus baccata* gives best results when treated for a period of 55 days.

Irregular germination is common in seeds of hybrid fruits. Seed of *Prunus Besseyi* (Western Sandcherry) is seldom obtained as a pure species, today, generally being a hybrid; the result of crossing with *Prunus pumila*. Irregular germination is common with this hybrid seed and it was found necessary to change previously reported requirements of 90 days to 90 to 140 days. Careful supervision is needed as the after-ripening period is being completed to guard against loss of seed. *Prunus japonica* has been found to give good germination after 110 to 115 days of after-ripening. Seed of *Prunus nigra*, given 140 to 150 days stratification, after three years of dry storage gave as satisfactory germination as fresh seed and there was no noticeable loss of viability. *Prunus Padus* has a required after-ripening period of 100 days. Seed of *Prunus siberica* will vary in its requirements from 45 to 60 days. Commercial apricot seed requires a longer period than the Siberian strains and gives a high germination after dry storage and an after-ripening period of 70 to 80 days. Irrespective of seed source or after-harvest treatment *Prunus tomentosa* has proven to be the most reliable. Sixty days of after-ripening gave complete germination with moist, not wet, sand used as a medium.

Good results have been obtained with *Sambucus* by carefully washing all pulp from the seed and seeding before it dries out. Storing the seed dry and stratifying for 40 days has proven satisfactory. This latter method

should be practised with early ripening varieties, so as to overcome danger of fall germination and subsequent loss.

Species of *Ampelopsis*, *Elaeagnus*, *Evonymus* and *Tilia* have seed that is difficult to handle under general nursery conditions and further work is required to simplify the recommendations as at present available.

GENERAL NOTES

Hot weather immediately following transfer of the seed to the seed-bed retards germination if the soil in the beds becomes too hot. Generous application of water aids in overcoming this difficulty. Excess moisture during cool weather encourages the development of "damping-off" organisms. Withholding moisture, increasing ventilation, and cultivation have been beneficial in overcoming these difficulties. As *Pyrus ussuriensis* is the most blight-resistant species of pear (3) and the hardiest introduced to the Station its seedlings are valuable for propagation purposes. They germinate readily with dry storage and an after-ripening period of 40 to 50 days. A high percentage of its seedlings are lost with twig blight during their first six months of growth. The blight resembles fire-blight but cultures have failed to isolate any organisms. Walnut and Butternut, and their hybrids, are also similarly affected. Seedlings of *Prunus chaemacerasus* and *Prunus maackii* are subject to "damping-off".

Peat moss, although excellent for its moisture-holding and anti-fungicidal properties, was found to injure seed of prematurely germinating stocks. This was likely due to its low pH value. Sand has been generally found to be a better stratifying medium, although it must be watched much more closely because of its tendency to dry out.

During late spring, root cellar ventilation requires careful attention. Wide changes in outside temperatures frequently cause sweating and seed boxes become excessively moist. Premature germination started in this way is very difficult to control.

ACKNOWLEDGMENT

Acknowledgment is made to Mr. J. A. McKay, Foreman of the Provincial Horticultural Station, whose careful attention to the practical application and observations made these findings possible.

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Name of Plant	Type of Seed	Best Storage	Treatment	Best temp. for after-ripening	Days for after-ripening	Usual method of propagation	Time of ripening	Remarks
				°F.				
Aesculus (Horse chestnut)	Nut	Moist	When ripe, pour into mosquito netting and bury 6" deep outside.			Seed	Spring	
Amelanchier (Saskatoon)	Hard-coated	Dry	After-ripen and sow in spring.	35 – 50	200	Root cuttings; Seed	Fall	Hard to germinate. Good practice to pick before fully mature and sow or stratify at once. Will germinate at 32° F. Time required varies so must be watched.
Crataegus (Hawthorn)	Hard-coated	Moist	After-ripen and sow in spring.	33 – 50	1 – 2 years	Seed	Fall	Remove seed coat with acid; this reduces after-ripening period from 2 years to 1 year. Gives fair germination with 195-day stratification.
Corylus cornuta (Beaked hazelnut)	Nut	Moist	When ripe stratify in clean sand and sow in spring.	33 – 50	90 plus	Seed; root cuttings	Fall	Sown outdoors takes 2 years to germinate. Preliminary study tends to show unequal dormancy in fresh seed. 170 days has given good results.
Juglans (Butternut, walnut)	Nut	Moist	When ripe place in mosquito netting bag and bury 6" deep outside and sow in the spring.			Seed; budding	Fall	Don't allow to completely dry out. 70 seeds per lb.

Malus (Apple; crabapple)	Tough coat	Moist or dry	After-ripen and sow in spring.			Cuttings; seed, layers	Fall	Stores well for 2½ years and still retains viability. The apples require 2 to 3 weeks longer than the crabapple for after-ripening.
Malus Baccata	Tough coat	Dry	After-ripen and sow in the spring.	33 – 50	55 – 60	Cuttings; seed layers	Fall	
Prunus besseyi (Western Sandcherry)	Hard-shelled	Moist or dry	After-ripen and sow in the spring.	33 – 50	140 – 150	Budding; seed, grafting	Early fall	
Prunus japonica glandulosa (Chinese bushberry)	Hard-shelled	Moist or dry	After-ripen and sow in the spring.	33 – 50	112		Early fall	
Prunus nigra (Canada native plum)	Hard-shelled	Moist or dry	After-ripen and sow in the spring.	33 - 50	150		Early fall	3 years of dry storage does not reduce viability of seed.
Prunus Padus (Birch cherry or Mayday tree)	Hard-shelled	Moist or dry	After-ripen and sow in the spring.	33 - 50	100	Seed	Early fall	
Prunus siberica (Siberian apricot)	Hard-shelled	Moist or dry	After-ripen and sow in the spring.	45 – 60			Early fall	Commercial varieties of apricot require a longer period and from 70 to 80 days is recommended.
Prunus Tomentosa (Nanking cherry)	Hard-shelled	Moist or dry	After-ripen and sow in the spring.	45 – 60	60	Seed	Summer	
Sambucus (Elder)	Tough coat	Moist or dry	Stratify and sow in the spring.		40 – 50	Seed		Uneven dormancy. Best to store, stratify, and sow very early in the spring.

SOME EFFECTS OF EXCESS BORON ON THE STORAGE QUALITY OF APPLES[1]

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[Received for publication July 9, 1942]

Since the discovery in New Zealand (1) and in British Columbia (7) that drought spot, corky core, and certain related disorders of the apple are due primarily to a deficiency of boron, considerable work has been done on methods of supplying boron to the plant, and on amounts required to produce satisfactory response. It was soon found (8) that excessive amounts of boron could be harmful to the foliage and thereby injurious to the tree. Little work has been reported, however, on the effects of excess boron on the fruit. In 1938, Chittenden and Thomson (4) reported an experiment with Jonathan apple trees, in which borax was applied to the soil around the trees at rates varying at $\frac{1}{2}$-pound intervals from 0 to 3 pounds per tree. The fruit was stored for 6 months at 38° F. With the higher applications of boron, more flesh breakdown developed in storage. A high positive correlation was obtained between the boron content of the fruit and the amount of breakdown. These findings were confirmed by the same authors (5) in 1940. They also found that with increasing applications of borax, the number of apples infected by fungal rot organisms increased. Both with breakdown and with rots, marked seasonal differences were noted. Somewhat similar results were obtained with borax sprays, though the correlations were not as significant as with the soil applications. In 1939, Burrell and Lewis (3) reported that they had found no marked effects of boron on the storage life of the apple.

In 1936, and annually since then, applications of borax and boric acid in varying amounts have been made to the soil around apple trees in the Dominion Experimental Substation orchard at Kelowna, B.C. Samples of the fruit from these trees have been used for storage studies. It is the purpose of this paper to present some of the results of these studies.

PROCEDURE

The apple trees selected for the boron investigations reported herein were all mature McIntosh and Jonathan trees, growing in a shallow sandy loam soil that contained no free carbonates. Prior to the initiation of these experiments, almost all of the trees were severely affected with drought spot, corky core, and other symptoms of boron deficiency (8). Those trees selected for special study were divided into two groups, in each of which a series of applications of borax and boric acid was made. In both groups the first applications were made in the spring of 1936. Since then, however, the times of application in the two groups have

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followed quite different schedules: in the one group (Series A) it was planned to make no further applications until symptoms of boron deficiency again became apparent; while in the other group (Series B), it was planned to repeat the applications annually until symptoms of boron excess became apparent. In Series A, two trees showed drought spot in 1936, and so were re-treated with boron in 1937. In Series B, two trees showed evidences of injury from excess boron in 1939, hence no further applications of borax or boric acid have been made to them since then. The tree numbers, varieties, and treatments are listed in Table 1.

TABLE 1.—LIST OF TREES AND TREATMENTS

Tree No.	Variety	Material applied	Amount applied	Dates of application
			oz.	
Series A				
J17	J*	borax	4	1936, 1937
J18	J	boric acid	4	1936, 1937
K16	M	borax	8	1936
K17	J	boric acid	8	1936
L15	M	borax	16	1936
L16	M	boric acid	16	1936
M14	M	borax	32	1936
M15	M	boric acid	32	1936
N13	J	borax	64	1936
N14	J	boric acid	64	1936
Series B				
O19	J	borax	1	1936, repeated annually
P21	M	boric acid	1	1936, repeated annually
O18	J	borax	2	1936, repeated annually
P20	J	boric acid	2	1936, repeated annually
P18	J	borax	4	1936, repeated annually
P19	J	boric acid	4	1936, repeated annually
Q16	M	borax	8	1936, repeated annually
P17	J	boric acid	8	1936, repeated annually
R17	M	borax	16	1936, repeated annually
Q17	M	boric acid	16	1936, repeated annually
R19	M	borax	32	1936, repeated annually
R20	J	boric acid	32	1936, repeated annually
S18	J	borax	64	1936, repeated till 1939
S19	M	boric acid	64	1936, repeated till 1939

*J—Jonathan, M—McIntosh.

Storage tests were made on samples of the fruit in 1936, 1938, 1939, and 1941. In 1936, the fruit from three McIntosh trees in Series A (Trees K16, L16, and M15) was graded for size and colour and placed in both cold (32° F.) and common storage. The same was done with the fruit from four McIntosh trees not treated with boron compounds or showing any evidences of boron deficiency. Three periodical examinations were made, involving pressure tests and various observational records on 40 apples per tree at each examination. Two pressure tests were made on each fruit, using a Ballauf pressure tester with 7/16-inch point. In 1938, fruit from all those trees in both series that bore a sufficiently heavy crop for the purpose was stored at 32° F. and at 60° F. In addition, fruit was stored from check (untreated) trees. With both the McIntosh and

Jonathan, only medium sized fruits of Fancy and Extra Fancy grades were selected for storage. At each periodical examination, 20 fruits were examined per tree. The same procedure was followed in 1939. In 1941, fruit from the Series B trees only was utilized. In an attempt to induce a large amount of storage breakdown, picking was delayed until after the commercial pickings of the same varieties had been completed. The dates of picking were September 15 and 26 for the McIntosh and Jonathan, respectively. The fruit was graded as in 1938, and was placed in common storage, with the temperature ranging around 60° F. At each recording, 20 fruits were examined per tree. The records obtained each year have included pressure tests, flesh colour and general appearance, water core and internal breakdown of the Jonathan, and flesh browning of the McIntosh.

In 1938 and again in 1939, samples of fruit were selected from each box as it was placed in storage, and analyses were made for boron. The method of analysis used has already been described in detail by Woodbridge (10).

RESULTS

This paper does not present a detailed report of the effects of borax and boric acid on the general tree behaviour. It should be stated, however,

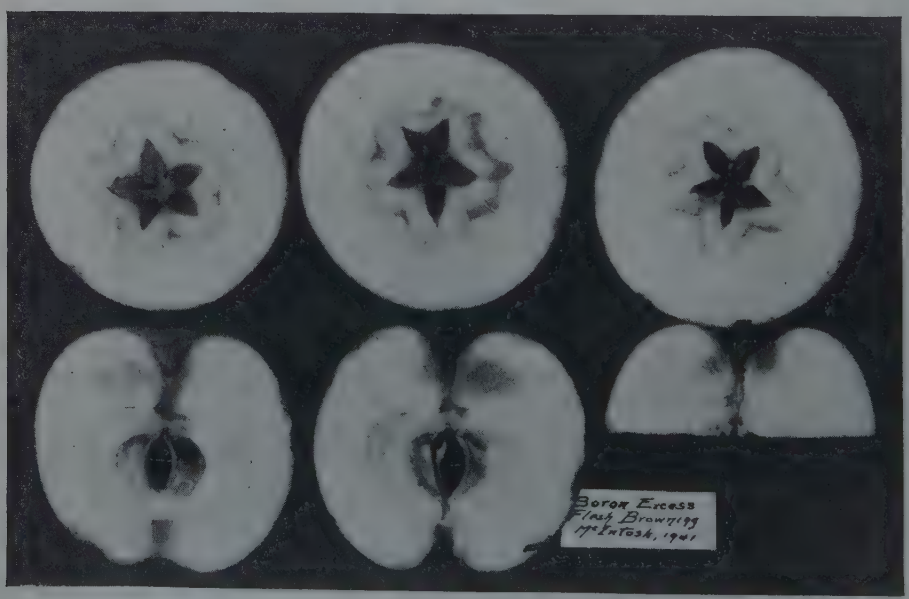

FIGURE 1.

FIGURE 1. A browning of the flesh of the McIntosh, induced by excessive applications of borax and boric acid to the soil. This browning appears in storage. It is confined almost entirely to the area around the core ring and to the flesh adjacent to the stem cacity. Compare with Figure 2.

(*Photo by J. E. Britton*)

that since 1936 no symptoms of boron deficiency have been noted on any of the trees. On the other hand, no symptoms of boron excess have been

noted except with trees S18 and S19, receiving annually four pounds each of borax and boric acid respectively. After four years of such treatment, the trees began to decline somewhat in vigour, and the fruit to become smaller and to develop an unnaturally dark blush. Consequently, in the following year the applications were discontinued on these two trees. The cover crop has been severely affected by applications not heavy enough to do visible damage to the trees (8).

Two types of injury to the fruit have been found to be induced or aggravated by excess boron. Both of them have developed in storage, one in the McIntosh and the other in the Jonathan. In the McIntosh (Figure 1), the primary bundles situated midway between the carpel points turn brown, and the discoloration then spreads outwards along the core line. The flesh also becomes discoloured around the stem cavity. In contrast with the core flush described by Eaves and Hill (6), and with the brown core described by Britton, Fisher, and Palmer (2), this browning does not occur inside the general area of the core lines. Brown core (Figure 2) is

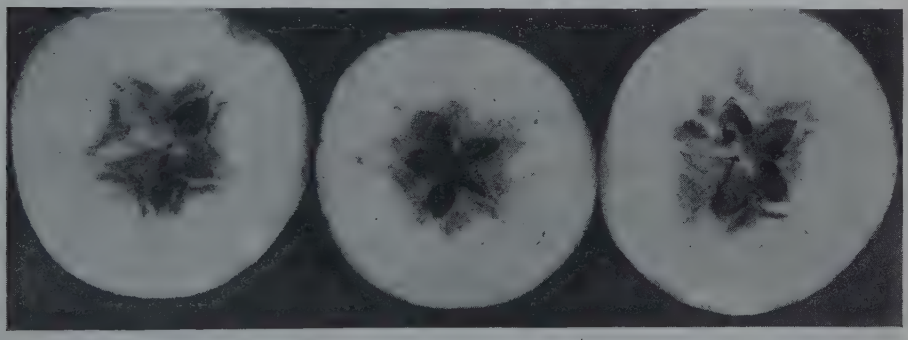

FIGURE 2.

FIGURE 2. Brown core (core flesh) of McIntosh, showing flesh breakdown immediately adjacent to the core. Compare with Figure 1.
(*Couresty Britton, Fisher and Palmer* (2).)

aggravated by cold storage, and appears to be induced by excessive vigour in the trees or by picking in an immature condition (2). The flesh browning induced by excess boron does not appear to be accompanied by any abnormal flavours in the flesh of the fruit.

In the Jonathan (Figure 3), what look like typical water core and flesh breakdown symptoms, as described by Palmer (9), have been increased by excess boron. The same relationships between these two disorders have been found as were noted by Palmer: (a) The two disorders were usually associated, the water core being a forerunner of the breakdown; (b) In some cases, however, the water core cleared up in storage and the fruit appeared normal; and in other cases breakdown appeared with no preceding symptoms of water core: (c) In many cases—especially when the injuries were severe—the water core persisted long after the appearance of the breakdown. This has occurred in 4 of the 6 specimens illustrated in Figure 3.

As the 1936 tests were largely preliminary, they will not be reported in detail. The heavier applications of borax and boric acid were found to induce the characteristic browning of the flesh of McIntosh fruits, described above. No browning was observed at picking time, and little was found on November 19. By January 15, however, even the fruits in cold storage showed considerable browning. There were no significant differences in pressure tests, either at picking time or later, among the different lots of fruit.

The 1938 data that are of special interest are summarized in Table 2. Water core was found to cause an increase, and flesh breakdown a decrease, in the pressure tests. Aside from this, there was no apparent effect of

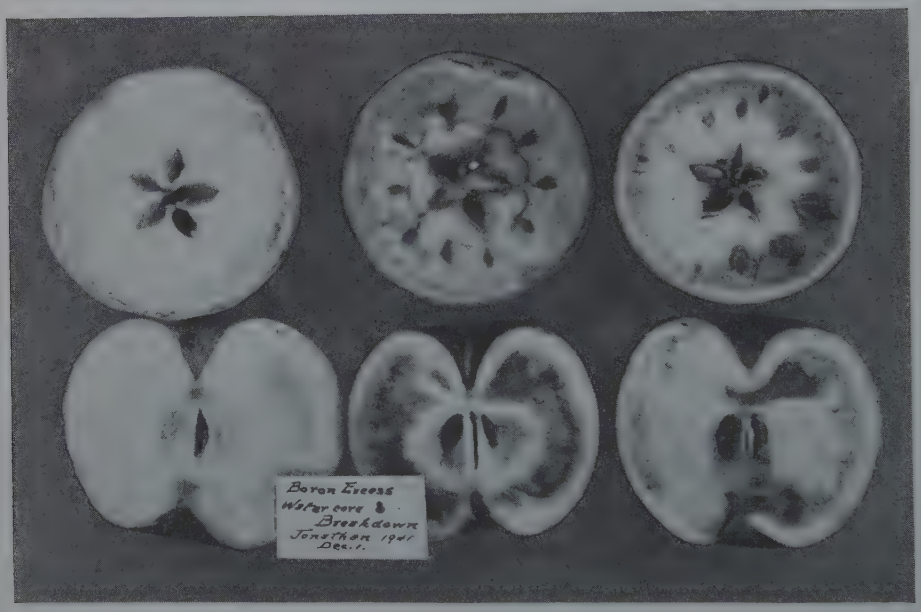

FIGURE 3.

FIGURE 3. Water core and flesh breakdown of the Jonathan, aggravated by excessive applications of borax and boric acid to the soil. The water core is usually in evidence by picking time, when present at all, but the breakdown develops entirely in storage. The two apples at the left are affected with breakdown, the other four with different combinations of breakdown and water core.

(*Photo by J. E. Britton*)

boron treatments on the firmness of the fruit, either at picking time or later. The pressure test data have therefore been omitted from Table 2. With only two of the McIntosh trees tested (F15 and S19) did the flesh browning occur with sufficient severity to affect the market value of the fruit. In both cases, the analyses of the fruits indicated high contents of boron.

Heavy applications of borax and boric acid were accompanied by considerable increases in water core and flesh breakdown in the Jonathan. The water core was present at picking time, and the breakdown had reached its maximum severity by December 16 in the 60° F. storage and at a later

date in the 32° F. storage. The breakdown data in Table 2 are for the 60° F. fruit only. Those fruits that developed the most water core usually developed the most breakdown. It should be noted that 1938 was an off year for both the McIntosh and Jonathan trees. A highly significant[4] positive correlation (0.812) was obtained between the boron applied to the soil and the boron content of the fruit (both varieties), and also between the boron content of the fruit and the flesh breakdown of Jonathan (0.832).

TABLE 2.—EFFECTS OF EXCESS BORON ON KEEPING QUALITY (AT 60° F.) OF MCINTOSH AND JONATHAN, 1938

Tree No.	Borax or boric acid applied in 3 years	Boron content of fruit (dry weight)	Flesh browning (Dec. 30)	Water core (Dec. 2)	Flesh breakdown (Dec. 30)	Yield
	oz.	p.p.m.	%	%	%	bu.
McIntosh						
I10	0	4.7	0			4
H11	8	11.6	0			3
K16 (A)*	8	12.3	0			8
Q16 (A)	24	13.9	0			4
L16 (A)	16	16.7	0			5
M15 (A)	32	24.1	3			7
F15	8†	24.3	37			3
S19 (B)	192	55.3	20			3
Jonathan						
O19 (B)	3	9.4		0	15	5
R3	0	10.1		0	0	4
O18 (B)	6	11.5		0	17	5
P18 (B)	12	11.8		4	20	4
F18	8	12.2		0	7	3
P20 (B)	6	13.2		6	20	4
P19 (B)	12	16.8		0	0	4
H14	8†	20.4		10	10	3
P17 (B)	24	30.4		8	37	3
R20 (B)	96	34.9		10	30	10
N14 (A)	64	41.2		18	42	6
N13 (A)	64	44.8		60	95	4
S18 (B)	192	74.8		70	80	5

* (A)—Series A, applications in 1936 only.
(B)—Series B, applications 1936 to 1938.
† Trunks injected with boric acid as well.

The 1939 data are shown in Table 3. Once again, there were no apparent effects of treatment on the pressure tests, except as noted above, and the pressure test data have therefore been omitted. Flesh browning of the McIntosh was severe enough in the fruits from four trees (R19, Q17, R17, S19) to affect their market value, but in only one case (S19) was any of the fruit rendered actually unsaleable. Although 10% of the fruits from tree L16 showed flesh browning, this was so slight as to be barely discernible. With the Jonathan, there was no water core and practically no breakdown. It should be noted that 1939 was a heavy-crop year, and that the Jonathans were picked just as the commercial harvesting of this variety was starting. In view of the previous findings of Palmer

[4] "Highly significant" refers to odds greater than 99 : 1, "significant" to odds between 99 : 1 and 19 : 1, and "non-significant" to odds less than 19 : 1.

(9), that breakdown of the Jonathan is less severe in a heavy-crop year, and that it is also less severe with early picking, the 1939 samples would not have been expected to develop a large amount of breakdown in storage. As in 1938, there was a highly significant positive correlation (0.884) between the borax or boric acid applied to the soil and the boron content of the fruit. The correlation between the boron content of the fruit and the percentage flesh browning of the McIntosh was not significant (0.552). This does not tell the whole story, however, as the higher percentages of browning were associated with a much more severe type of injury.

TABLE 3.—EFFECTS OF EXCESS BORON ON KEEPING QUALITY (AT 60° F.) OF MCINTOSH AND JONATHAN, 1939

Tree No.	Borax or boric acid applied in 4 years	Boron content of fruit (dry weight)	Flesh browning (Jan. 4)	Water core (Nov. 8)	Flesh breakdown (Jan. 4)	Yield
	oz.	p.p.m.	%	%	%	bu.
McIntosh						
L15 (A)*	16	6.9	0			4
L16 (A)	16	8.8	10			25
K16 (A)	8	9.5	0			27
W11	8	13.0	0			22
M15 (A)	32	16.9	3			20
R19 (B)	128	22.4	19			25
Q16 (B)	32	23.9	0			32
Q17 (B)	64	28.4	29			29
R17 (B)	64	45.2	17			18
S19 (B)	256	82.4	44			22
Jonathan						
G3	0	6.5		0	0.8	12
P20 (B)	8	10.3		0	0.0	26
P18 (B)	16	10.3		0	0.8	20
J18 (A)	8	11.6		0	0.0	15
O19 (B)	4	12.0		0	2.5	30
O18 (B)	8	15.8		0	0.0	14
K17 (A)	8	15.8		0	0.0	10
P19 (B)	16	16.6		0	0.0	31
S13	8	19.8		0	1.5	19
N14 (A)	64	28.4		0	0.0	17
P17 (B)	32	31.0		0	0.0	19
R20 (B)	128	38.2		0	0.0	21
N13 (A)	64	42.0		0	0.0	13
S18 (B)	256	73.7		0	0.8	24

* (A)—Series A, applications in 1936 only.
(B)—Series B, applications 1936 to 1939.

The 1941 data are summarized in Table 4. It is unfortunate that no fruit was stored from McIntosh trees receiving low amounts of boron. There was a definite tendency, however, for the heaviest applications of boron to be accompanied by the most severe flesh browning. The fruit from tree S19 was definitely unmarketable. Although most of the Jonathan trees bore fairly heavily this year, the delay in picking was apparently instrumental in causing a marked increase in both water core and breakdown, in comparison with 1939. The results are similar to those obtained in 1938, an off year. With both varieties, the fruits from the trees receiving

TABLE 4.—EFFECTS OF EXCESS BORON ON KEEPING QUALITY (AT 60° F.) OF McINTOSH AND JONATHAN, 1941

Tree No.	Borax or boric acid applied in 6 years	Flesh browning (Nov. 22)	Water core (Sept. 30)	Flesh breakdown (Nov. 22)	Yield
	oz.	%	%	%	bu.
McIntosh					
Q16*	48	7			30
R17	96	50			4
Q17	96	22			12
R19	192	45			11
S19	320	77			7
Jonathan					
O19	6		20	17	17
P20	12		0	0	25
P18	24		70	2	30
P19	24		20	2	27
P17	48		65	5	20
R20	192		80	47	16
S18	320		100	87	24

* All of the trees listed are in Series B, receiving annual applications of borax or boric acid.

the most boron were the ones most severely affected. In contrast with 1938, it will be noted from Table 4 that in some cases a large proportion of the water core disappeared early in the storage life of the apple, being followed by much lower percentages of breakdown. This did not occur to such an extent where the water core spread throughout the flesh of the fruits (trees R20 and S18).

OBSERVATIONS AND CONCLUSIONS

The results of the work to date point to the following observations and conclusions:

1. Heavy applications of borax or boric acid to the soil will, under certain circumstances, induce a characteristic browning of the flesh of McIntosh, and will also increase the amount of water core and flesh breakdown in the Jonathan.

2. A lowering of the storage quality of the fruit may occur before there are any readily discernible evidences of injury from excess boron to the leaves or twigs of the trees.

3. The injury to the fruit (as described) has been closely associated with a high boron content of the fruit. When the season is conducive to fruit injury, this injury is more likely to occur, and to be commercially detrimental, when the boron content of the fruit is higher than about 24 p.p.m. on the dry weight basis. The results obtained by Chittenden and Thomson (4, 5) were somewhat similar. It is of interest to note that Woodbridge (10) found that less than 6 to 7 p.p.m. of boron in the fruit may constitute a serious deficiency. Thus the optimum range appears to be rather narrow. Indeed, it appears possible that in certain season the

optimum may fall between the very narrow limits of about 10 and 20 p.p.m. It is quite probable, however, that in most seasons a much wider range than this will not be commercially detrimental to the fruit.

4. Seasonal differences and amount of crop affect the degree of injury to the fruit. Thus in 1939 even the heaviest applications of borax or boric acid caused no apparent injury to Jonathan fruits, whereas in 1938 and 1941 the heavier applications were accompanied by both severe water core and severe flesh breakdown.

5. Storage troubles that are increased by excess boron may still occur even when boron is apparently not present in excess. Thus in 1941, storage breakdown developed in 17% of the fruits from tree O19, which had received a total of only 6 ounces of borax over a 6-year period. Observations made in the Substation orchard in 1940—a light-crop year with the Jonathan—indicated that under certain circumstances even fruit from trees not treated with boron compounds might develop severe water core and flesh breakdown.

6. Attention should be drawn to those rates of application that were found in 1938 and 1939 to cause a higher boron content of the fruit than 24 p.p.m. In 1938, boron contents higher than this were found in fruits from one tree that had received 32 ounces of boric acid three years previously, from two trees that had received 64 ounces of boric acid three years before, and from six trees that had received 8 ounces or more of borax or boric acid each year for three years. In 1939, the high-boron fruits came from the two trees that had received 64 ounces four years previously, and from nine trees that had received 8 ounces or more each year for four years. It is unfortunate that complete storage tests were not conducted immediately following the first year of treatment. The information obtained, however, indicates that deleterious effects on the storage quality of apples are possible when more than two pounds of boric acid or its equivalent is applied to each tree in any one year, or when 8 ounces or more are applied annually to each tree. These findings are of course not necessarily applicable to other soil types or other environmental conditions than those occurring in this experiment.

SUMMARY

McIntosh and Jonathan trees were treated with soil applications of borax and boric acid. In one series, applications of 4 ounces to 4 pounds per tree were made in 1936. In a second series, applications of 1 ounce to 4 pounds per tree were made annually from 1936 to 1941. Storage tests were made on the fruit in 1936, 1938, 1939, and 1941, and boron analyses were made in 1938 and 1939.

The heavier applications of borax and boric acid induced a characteristic browning of the flesh of the McIntosh. This browning was confined almost entirely to the core ring and to the flesh around the stem cavity. Only with the heaviest applications of boron, however, was the injury severe enough to tender the fruit unmarketable. With the Jonathan, water core and flesh breakdown were increased by the excessive applications of boron. This occurred in 1938, an off year, and (with late picking) in

1941, an on year. Almost no water core or breakdown occurred in 1939, an on year, when the fruit was picked early.

High positive correlations were found between the rate of application of boron to the soil and the boron content of the fruit, and between each of these and the amount of injury to the fruit. A lowering of the commercial value of the fruit was found to be more likely to occur when the boron content was 24 p.p.m. (dry weight) or higher. This was achieved with a single application of 2 pounds or more of borax or boric acid per tree, or with annual applications of 8 ounces or more per tree.

ACKNOWLEDGMENTS

The authors wish to express their appreciation for the many valuable suggestions made throughout the course of this work by Dr. H. R. McLarty, Officer-in-charge of the Laboratory of Plant Pathology at Summerland, B.C.; and by Mr. R. C. Palmer and Mr. J. E. Britton of the Dominion Experimental Station at Summerland. They also wish to acknowledge photographic assistance given by Mr. J. E. Britton, and editorial suggestions made by Dr. D. V. Fisher of the Dominion Experimental Station at Summerland.

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COMPARATIVE STUDIES IN THE PREVENTION OF WOOD TAINT, TOPPINESS AND PRIMROSE COLOUR OF STORAGE BUTTER

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[Received for publication July 15, 1942]

Surface defects of creamery butter such as wood taint, toppiness and primrose colour have assumed considerable significance in recent years. The very nature of these defects, occurring as they do, only on the surface of the cube of butter, suggests that the package is at fault. Among the more promising proposals for the prevention of butter surface defects have been the casein-formalin treatment of the interior surfaces of the butter box, the parch-foil liner, and the avenized parchment liner. Considerable work has also been done to compare woods from which boxes may be made.

The experimental results reported in this paper were undertaken with four main objects in mind, namely the comparison of:—

(1) Spruce *Picea glauca* (Moench) Voss and Poplar *Populus tremuloides* Michx woods for butter boxes.

(2) Paraffin, casein-formalin and no treatment at all for the inside of butter boxes.

(3) Ordinary parchment, avenized parchment, and two makes of parch-foil as liner materials.

(4) All possible combinations of the above mentioned woods, inside box treatments and liner materials.

At the outset it was realized in connection with the fourth object that many of the combinations would probably be entirely unsuitable, but the desire was to establish as true a measure as possible of the value of each combination used.

The completion of this work led to a second experiment in which nine of the most promising packages, together with two additional packages, were compared with the standard pack.

REVIEW OF LITERATURE

Singleton (1) pointed out, as early as 1926, that a considerable quantity of New Zealand butter was being criticized on the London market because of a woody flavour on the surface of the block. The defect became more pronounced and permeated farther into the block of butter, as the storage period was extended. He associated this flavour with pockets of resin in the butter box wood. Wiley (2) made a study of the problem in 1932, reporting that the objectionable flavour was due to absorption by the butter of "...substances in the wood, insoluble in water, soluble in petrol ether, and readily volatile in steam." He reported that seasoning did not lead to

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an appreciable loss of these substances but Hood (6), working with Canadian spruce and balsam, found that unseasoned lumber tainted the butter much more severely than did seasoned lumber. Wiley (3, 4) proposed a casein-formalin spray treatment for butter boxes as a means of overcoming this wood taint. Regarding the use of paraffined boxes he stated that "The experience of many Australian factories has shown this treatment to be quite ineffective in preventing taint. From the nature of the materials causing taint, this is what might be anticipated." Hood (6, 9) found wood taint very prevalent in paraffined boxes while Thomsen (10) concluded that there was "...no advantage in paraffining tubs when they are to be used for storing salted butter." Wiley's casein-formalin treatment was studied by Hood (6, 9, 13), Riddet, Valentine and McDowall (7), McDowall and Smith (12) and Cosgrave (21). All reported considerable reduction in the incidence and intensity of wood taint when the treatment was used, but found that it did not entirely prevent the defect.

Barnicoat (5) appears to have been one of the first to study means of preventing a tallowy or oxidized surface flavour and high surface colour. He referred to the former defect as toppiness and to the latter as primrose colour. His work showed that primrose colour was due to surface desiccation and that it, as well as toppiness, could be effectively prevented by using a box liner made of tinfoil over parchment. He later found that aluminum foil liners greatly retarded the development of toppiness (19). Of the various liner materials studied by Riddet *et al.* (8), tin and aluminum foil parchment liners were found to be the most satisfactory. Hood and White (14) and Brown (20) came to the conclusion that aluminum foil parchment[3] liners gave greater protection to butter surfaces than did the other liners used by them. At the same time they found that this type of liner entirely prevented primrose colour. Cosgrove (21) reported on a trial shipment of 11,000 boxes (made from Canadian hemlock) of butter from Australia to London. Some of these boxes were untreated and lined with parch-foil, while others were casein-formalin treated and lined with parchment. The former containers had a strong woody smell when the butter was stripped, but the parch-foil liners had successfully protected the surface of the butter from both wood taint and oxidation. The treated boxes lined with parchment did not offer as satisfactory protection.

Peters and Musher (15) suggested the use of avenized parchment (parchment treated with oat flour) as a means of protecting butter surfaces against oxidation. Dahle and Josephson (16), Koening (17) and Corbett and Tracy (18) studied the use of this material for wrapping butter prints. All found it to give greater protection than ordinary untreated parchment.

The first parch-foil liners available could not be subjected to any sterilizing process and some fears were expressed regarding the development of mould. Riddet and Neil (11) showed, however, that parch-foil liners prevent mould from penetrating from infected boxes to the surface of the butter. Brown (20) found no trouble with mould using untreated parch-foil liners. He also reported that, from the standpoint of mechanical use, these liners were easily handled.

[3] Hereafter called parch-foil in this report.

METHODS

The data reported in this paper resulted from two experiments, the first being carried out in 1938–39 and the second in 1939–40. The first experiment consisted of a comparison of 24 packages. These packages, made up of all possible combinations of 2 kinds of box wood, 3 kinds of box treatment and 4 different liners, are described in Table 8. One box of each pack was prepared from each of 6 churnings, making a total of 144 boxes in all.

On the basis of the results from the first experiment, nine packages were selected for more extensive study in the second experiment. For comparative purposes the standard pack[4] was included in both experiments. Two parch-foil liners, placed on the market some time after the first experiment was started, were also included in this study. This made a total of 12 packages in the second experiment, which are described in Table 9. Two boxes of each pack were prepared from each of 10 different churnings, making 20 boxes of each pack available for comparisons, instead of 6 as in the first experiment, or a total of 240 boxes in all.

Seven-pound boxes were used throughout the two experiments. They were contructed of material of the same thickness as that used in the standard 56 pound box and only well seasoned stock was used.

Liners were obtained through regular trade channels. In the first experiment the parchment liners were sterilized in boiling sodium chloride brine and were used wet. The parch-foil liners were used dry in this experiment. Since no mould growth was apparent in the first experiment using untreated liners, all liners were used untreated in the second experiment.

Parchment liners weighed 40 pounds per ream and always were used double thickness.

First grade butter was used in all cases, but no effort was made to select churnings of exceptionally high quality. The interior of several blocks of butter from each churning was examined by the graders at the same time that they examined the surface of the blocks. In no case did the interior flavour scores of the churnings drop below 39⁻ . Lining, packing and finishing of the boxes were carefully done to ensure that surfaces of the blocks received the maximum protection provided by the particular package used. The butter in the first experiment was stored for approximately 8 months at 0° F. or lower, while that in the second experiment was stored for approximately $9\frac{1}{2}$ months at the same temperature. Surfaces of the butter blocks were examined by three Dominion Dairy Produce Graders at the completion of the storage periods. The terms used by the graders to indicate the extent of undesirable surface flavour developed, together with the values assigned to these terms for purposes of calculation, are shown in Table I. The graders found the interval between specific terms, such as between "absent" and "trace", too great and hence made use of the symbols + and −. A + symbol was used to indicate slightly less surface flavour (superior flavour) while a − symbol was used to indicate slightly more surface flavour.

[4] Paraffined spruce boxes lined with two thicknesses of 40 pound parchment.

TABLE 1.—NUMERICAL VALUES ASSIGNED TO TERMS USED BY GRADERS TO INDICATE EXTENT OF UNDESIRABLE SURFACE FLAVOUR

Term	Value Assigned
A	10
A^- or T^+	9
T	8
T^- or D^+	7
D	6
D^- or S^+	5
S	4
S^- or $V.S.^+$	3
V.S.	2
$V.S.^-$	1

A = absent, T = trace, D = definite, S = strong, V.S. = very strong.

Three surfaces of each block of butter were examined in the first experiment, the top, one side and the bottom. In the second experiment only the top and one side were examined.

The testing of all possible combinations of box wood, box treatment and liners, in the first experiment, provided a factorial design in which the significance of various effects and their interactions could be determined by the analysis of variance. The analyses are not reproduced here but were used to provide the standard deviations reported in the tables and as a guide in the detection of significant effects.

The words "pack" and "package" are used throughout this report to refer to any one treatment combination of box wood, inside box treatment and liner.

RESULTS

Half of the boxes used in the first experiment were made of poplar and half of spruce. Table 2 is arranged to simplify comparison of these two woods as material for butter boxes.

TABLE 2.—MEAN SURFACE FLAVOUR SCORES AND STANDARD DEVIATIONS OF BUTTER STORED IN POPLAR AND SPRUCE BOXES

Box wood	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
Poplar	72	216	7.90	1.88
Spruce	72	216	8.54	1.87

Under the varied conditions of this experiment, spruce boxes averaged 0.64 points per surface, in flavour score, higher than did poplar boxes. Both kinds of wood, however, showed considerable variation in their ability to protect butter surfaces. This is indicated by the high standard deviations and was partly due to the different inside box treatments used, as illustrated in Table 3.

TABLE 3.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS AS INFLUENCED BY THE INSIDE BOX TREATMENTS USED

Box treatment	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
None	48	144	7.51	1.97
Paraffin	48	144	8.26	1.97
C–F*	48	144	8.90	1.46

* Casein-formalin.

The standard deviation for the casein-formalin treatment was considerably lower than that of the other two inside box treatments, while the mean score per surface was substantially higher. These data indicate superior qualities over those of the other two. Paraffined boxes, though inferior to casein-formalin treated boxes, provided greater protection to butter surfaces than did untreated boxes.

TABLE 4.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS AS INFLUENCED BY THE FOUR DIFFERENT LINERS USED

Liner	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
Parchment	36	108	7.31	2.30
Avenized parchment	36	108	8.59	1.54
Parch-foil 1	36	108	9.63	0.59
Parch-foil 2	36	108	7.36	1.66

Comparison of the data in Table 4 brings out the chief cause for the rather high standard deviations shown in Tables 2 and 3. Parchment liners, for instance, were particularly susceptible to variable results, while parch-foil 1 gave uniformly high protection. The high mean score per surface of 9.63 obtained by parch-foil 1 may be attributed to the fact that it provided good protection to butter surfaces, regardless of the box and box treatment it was used with.

TABLE 5.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS OF THE THREE INSIDE BOX TREATMENTS AS INFLUENCED BY THE BOX WOOD

Box wood	Box treatment	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
Poplar	None	24	72	7.12	1.87
	Paraffin	24	72	7.89	2.00
	C–F	24	72	8.69	1.39
Spruce	None	24	72	7.89	2.00
	Paraffin	24	72	8.62	1.87
	C–F	24	72	9.11	1.51

The influence that box wood had on the effectiveness of box treatments is shown in Table 5. All box treatments obtained higher mean scores per surface (*i.e.* provided greater protection to butter surfaces) when used with spruce than they did when used with poplar boxes. Table 6 reveals that somewhat different results were obtained with the liners when used in the two kinds of boxes.

TABLE 6.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS OF THE FOUR LINERS AS INFLUENCED BY THE BOX WOOD

Box wood	Liner	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
Poplar	Parchment	18	54	6.67	2.06
	Avenized parchment	18	54	7.76	1.62
	Parch-foil 1	18	54	9.70	0.50
	Parch-foil 2	18	54	7.48	1.45
Spruce	Parchment	18	54	7.94	2.37
	Avenized Parchment	18	54	9.43	0.86
	Parch-foil 1	18	54	9.56	0.66
	Parch-foil 2	18	54	7.24	1.85

Both kinds of parchment liners obtained higher mean scores per surface with spruce. On the other hand the parch-foil liners obtained higher scores with poplar boxes. One outstanding feature of Table 6 is the high mean score per surface (9.70) and the low standard deviation obtained by the poplar–parch-foil 1 combination. Parch-foil 1 obtained relatively high average scores per surface regardless of the kind of wood used in the construction of the box (Table 6) or the treatment given the inside of the box (Table 7).

TABLE 7.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS OF THE FOUR LINERS AS INFLUENCED BY THE BOX TREATMENT

Box treatment	Liner	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
None	Parchment	12	36	5.78	1.76
	A–P*	12	36	7.50	1.65
	Parch-foil 1	12	36	9.47	0.61
	Parch-foil 2	12	36	7.28	1.60
Paraffin	Parchment	12	36	7.36	2.50
	A–P	12	36	8.69	1.37
	Parch-foil 1	12	36	9.86	0.49
	Parch-foil 2	12	36	7.11	1.56
Casein-formalin	Parchment	12	36	8.78	1.50
	A–P	12	36	9.58	0.65
	Parch-foil 1	12	36	9.56	0.61
	Parch-foil 2	12	36	7.69	1.80

* A–P = Avenized parchment.

The mean scores per surface for parch-foil 1 are consistently high throughout Table 7 and at the same time the standard deviations are consistently low. The casein-formalin, avenized parchment combination is the only other pair in Table 7 which combines the desirable features of a high mean score with a low standard deviation.

TABLE 8.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS OF THE 24 DIFFERENT PACKAGES TESTED IN THE FIRST EXPERIMENT

Box wood	Box treatment	Liner	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
Poplar	None	Parchment	6	18	5.56	1.38
		A–P	6	18	6.33	1.33
		Parch-foil 1*	6	18	9.39	0.61
		Parch-foil 2	6	18	7.22	1.35
	Paraffin	Parchment	6	18	6.56	2.46
		A–P	6	18	7.72	1.23
		Parch-foil 1*	6	18	9.94	0.24
		Parch-foil 2	6	18	7.33	1.57
	C–F	Parchment	6	18	7.89	1.57
		A–P*	6	18	9.22	0.73
		Parch-foil 1*	6	18	9.78	0.43
		Parch-foil 2	6	18	7.89	1.41
Spruce	None	Parchment	6	18	6.00	2.09
		A–P	6	18	8.67	0.97
		Parch-foil 1*	6	18	9.56	0.62
		Parch-foil 2	6	18	7.33	1.85
	Paraffin	Parchment*	6	18	8.17	2.33
		A–P*	6	18	9.67	0.59
		Parch-foil 1*	6	18	9.78	0.65
		Parch-foil 2	6	18	6.89	1.57
	C–F	Parchment*	6	18	9.67	0.69
		A–P*	6	18	9.94	0.24
		Parch-foil 1	6	18	9.33	0.69
		Parch-foil 2	6	18	7.50	2.15

* Combinations marked with this symbol were studied more intensively in the second experiment.

Table 8 presents mean scores per surface and standard deviations for each of the 24 different packages studied in the first experiment. Certain features of this Table are worthy of special note. (1) The avenized parchment liner gave good results (high mean score per surface and low standard deviation) where it was used in connection with casein-formalin treated boxes and in the case of the paraffined spruce box. (2) The spruce, casein-formalin, parchment package was the only combination in which ordinary 40-pound parchment gave comparatively good results. (3) Packages which consisted, in part, of parch-foil 2 were consistently poor and in some instances were less satisfactory than similar packages in which ordinary parchment was used as the liner material. (4) Eleven of the packages show more satisfactory protection to butter surfaces than does the standard package. (5) The 6 packages in which parch-foil 2 was involved all show lower mean scores per surface than does the standard package.

In addition to indicating the extent of an objectionable flavour, if any, by one of the terms shown in Table 1, the graders also attempted to describe the flavour defects encountered. "Woody", was used on 26 occasions to describe the flavour causing a lowering of the surface score. It was used 19 times in connection with butter packed in poplar boxes to only 7 times with butter packed in spruce boxes. Comparing the box treatments, the term "woody" was used 16 times where the box had received no treatment, 7 times where paraffined boxes were used and only 3 times where the boxes had been treated on the inside with casein-formalin sprays. Making the comparison as between parchment and parch-foil liners, "woody" was used 25 times in connection with parchment liners to only once with parch-foil.

Parch-foil 2 seemed to be associated particularly with a surface flavour which the graders described as "objectionable". This term was used 14 times in connection with parch-foil 2 and 4 times with parchment but was never mentioned iu connection with parch-foil 1.

Another term used by the graders to describe an undesirable flavour, was "fishy" or "fishy tendency". It seemed to be associated chiefly with parchment liners, since out of the 9 times it was used, 7 of these were in connection with parchment liners. In the other two instances it was used with parch-foil 2.

Other undesirable flavours described by the graders as unclean, oxidized, tallowy and storage were encountered to a limited extent. They were always associated with either parchment or parch-foil 2 liners.

As stated under "Methods", 9 of the more promising packages of the first experiment were selected for more extensive study. These were compared with the standard package and with two new parch-foil liners (listed respectively as Nos. 3 and 4) which had been placed on the market after the first experiment was underway. The data of this experiment are summarized in Table 9.

Of the 12 packages tested in this experiment, the standard package gave the least satisfactory protection against surface flavour defects. The mean score per surface of 7.52 is the lowest in the Table while the standard deviation is the highest. The spruce, casein-formalin, avenized parchment package provided the greatest protection, having the highest mean

TABLE 9.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS OF PACKAGES TESTED IN THE SECOND EXPERIMENT. PACKAGES ARRANGED IN ORDER OF THEIR ABILITY TO PREVENT SURFACE DETERIORATION OF BUTTER PACKED THEREIN

Description of package			No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
Box wood	Box tr't.	Liner				
Spruce	C–F	A–P	20	40	9.65	0.74
Spruce	Paraffin	A–P	19*	38	9.45	0.95
Spruce	Paraffin	Parch-foil 1	20	40	9.42	0.71
Poplar	Paraffin	Parch-foil 1	20	40	9.42	1.78
Spruce	Paraffin	Parch-foil 4	20	40	9.28	1.09
Poplar	C–F	A–P	20	40	9.22	0.80
Poplar	None	Parch-foil 1	20	40	9.12	0.94
Poplar	C–F	Parch-foil 1	20	40	9.10	0.87
Spruce	C–F	Parchment	20	40	9.10	1.19
Spruce	None	Parch-foil 1	20	40	9.10	1.45
Spruce	Paraffin	Parch-foil 3	20	40	8.72	1.04
Spruce	Paraffin	Parchment	20	40	7.52	2.28

* One box of this package was lost while in storage.

score per surface and almost the lowest standard deviation. This combination however, was only slightly superior to the 3 packages immediately following it in the Table. The poplar, paraffin, parch-foil 1 combination is placed below the spruce, paraffin, parch-foil 1 package because of its relatively high standard deviation. The other packages follow in the order shown in Table 9.

In order to interpret correctly the standard deviations shown in Table 9 it is necessary to know what variable factors were responsible for deviations from the means. The variance of any one package can be divided into two parts, that due to differences in the behaviour of the package between different churnings and that due to differences in the surface flavour between boxes from the same churning and surfaces of the same box. The former is referred to as the churning variance and the latter as sampling variance. Analysis of variance showed that with all packages the churning variance was greater than the sampling variance. This indicates (1) that there was considerable difference between churnings as regards their susceptibility to undesirable surface flavours and (2) that the technique used in preparing and packing the individual boxes was reasonably satisfactory.

Table 10 was prepared to illustrate the differences between the three parch-foil liners studied in the second experiment. It is evident that these liners differ greatly in their ability to protect butter surfaces.

All boxes of butter in the two experiments were examined for primrose or high surface colour. Only one, of the 212 boxes lined with parch-foil, was criticized for this defect, while, of the 172 boxes lined with parchment, 93, or 55% showed a higher colour on the surface than in the body of the block.

In the second experiment as in the first, no mould growth was evident when the butter was examined by the graders.

TABLE 10.—MEAN SCORES PER SURFACE AND STANDARD DEVIATIONS FOR THREE PARCH-FOIL LINERS TESTED IN PARAFFINED SPRUCE BOXES

Liner	No. of boxes	No. of surfaces	Mean score per surface	Standard deviation
Parch-foil 1	20	40	9.42	0.71
Parch-foil 3	20	40	8.72	1.04
Parch-foil 4	20	40	9.28	1.09

DISCUSSION

In carrying out the work reported in this paper the authors were impressed by the fact that making comparisons between woods, box treatments or liners is likely to lead one to false conclusions. Rather the comparisons should be made between packages when considered as a whole. For instance, Table 2 shows that butter packed in spruce boxes had less undesirable surface flavour than did butter from the same churnings, packed in poplar boxes. This, however, does not mean that poplar should be condemned as a material for butter boxes. An examination of Tables 8 and 9 shows several packages, in which the box made of poplar, stands well above the standard package in mean score per surface. The same point can be illustrated with box treatments or liners. Table 3 shows paraffin superior to no treatment and casein-formalin superior to paraffin, yet in Table 9 two packages, in which the box was untreated, were much more satisfactory than the standard package. Again, Table 4 shows parch-foil 1 as far more staisfactory than avenized parchment (under the conditions of the experiment) yet the latter liner, combined with the casein-formalin treated spruce box, proved to be the most satisfactory of all packages shown in Table 9. These illustrations clearly show that in the final analysis, the comparisons should be made between packages as a whole and that comparisons between individual components of the package may lead to entirely erroneous conclusions.

The surface flavours encountered in this work may be divided into two main groups, those emanating from the package itself and those brought about by a chemical change in the surface layer. In the former group may be placed woody flavour and the so-called "objectionable" flavour encountered almost entirely where parch-foil 2 was used. The other flavours, fishy, fishy tendency, oxidized, tallowy and storage more probably belong in the latter group.

A package, to be satisfactory, should guard against contamination of the butter with volatile substances from the box, should not contain any substances, which, in themselves, will cause an undesirable flavour and should protect the butter surfaces from too rapid oxidation. The latter may be accomplished either by exclusion of air or by virtue of an anti-oxidant incorporated in the liner. Finally, if primrose colour is to be avoided, the package must also prevent evaporation of moisture from the surface layer of butter.

To adequately interpret the data reported in this paper, these general statements should be borne in mind. Failure to do so may lead to the

rejection of a particular box wood, box treatment, or liner, which when used in proper combination with other constituents of the package, may give entirely satisfactory results.

Poplar (*Populus tremuloides* Michx) as a material for butter boxes has certain advantages over the standard spruce (*Picea glauca* (Moench) Voss.). It is a tough wood which shows little tendency to crack or splinter when nailed or when subjected to the rough treatment involved in repeated handling. On the other hand it is rather easily soiled and has the added disadvantage of possessing a strong odour which readily penetrates paraffin and parchment to contaminate butter surfaces.

The data presented clearly demonstrate that poplar boxes, when used either paraffined or untreated and with parchment liners, are more likely to produce a woody surface flavour than spruce boxes. They also demonstrate, however, that the dangers of woody flavour from poplar boxes, or for that matter, spruce boxes, are largely removed, if the casein-formalin treatment is used. This is in agreement with the findings of Wiley (2, 3, 4), Hood (6, 9, 13), Riddet, Valentine and McDowall (7), and Cosgrave (21).

While the casein-formalin treatment gave a large measure of protection against woody flavour, it did not prevent, or even noticeably retard, the other class of undesirable flavours caused by oxidation. The avenized parchment liner when used with the casein-formalin treatment, provided the anti-oxidant necessary to guard against this type of flavour defect. It did not, however, possess the property of preventing surface desiccation and consequently did not reduce materially the incidence of primrose colour.

Parch-foil 1 provided good protection against both types of flavours and against primrose colour, regardless of the box wood or box treatment used. Table 9, however, indicates that there is some advantage in favour of paraffined boxes when this liner is used. At present, with wartime needs holding precedence over others, the use of aluminum foil in butter liners is precluded, but with the cessation of hostilities this type of liner should gain in popularity.

The very great differences between parch-foil liners is rather surprising. Previous reports (5) (8) (14) (19) (20) (21) have not noted such differences. Parch-foil 2 had little to recommend it, except that it did prevent primrose colour. The "objectionable" surface flavour often noted when this liner was used may have been due to the adhesive used in cementing the parchment to the aluminum foil. Parch-foils 3 and 4 were much superior to 2 but less satisfactory than parch-foil 1.

Assuming that parch-foil liners will not be available for some time to come, it would seem that the most logical solution to the surface flavour defects mentioned in this study lies in the casein-formalin treatment and the avenized parchment liner. Table 9 shows that avenized parchment liners used with paraffined or casein-formalin treated spruce boxes provided much greater protection than the standard spruce, paraffin, parchment package now in use. Should a shortage of spruce develop, casein-formalin treated poplar boxes could be substituted with almost as satisfactory results.

Another angle to this problem and one which has not been studied as yet is the great difference in the susceptibility to surface oxidation between different churnings of butter. With some churnings almost any package proved to be satisfactory so long as precautions were taken to guard against woody flavour. With others even the best package failed to provide complete protection.

SUMMARY

1. Twenty-six packages for storage butter, differing in one detail or another, have been tested during a two-year period.

2. The study included a comparison of poplar *Populus termuloides* Michx and spruce *Picea glauca* (Moench) Voss as material for butter boxes, no treatment, paraffin and casein-formalin as inside box treatments and ordinary 40 pound parchment, avenized 40 pound parchment and four brands of parch-foil as liner materials.

3. In all, 912 surfaces of 384 boxes of butter were examined.

4. Poplar boxes had a greater tendency to produce wood taint in the butter than did spruce boxes, but when used in combination with parch-foil liners this defect was overcome.

5. Paraffin, as a treatment for butter boxes, reduced the incidence of wood taint over untreated boxes but could not be considered as a satisfactory safeguard against this defect.

6. The casein-formalin treatment of boxes almost completely eliminated wood taint but appeared to be of no value in preventing toppiness and other undesirable surface flavours.

7. All brands of parch-foil liners, regardless of box wood or box treatment, gave complete protection against primrose colour and almost complete protection against wood taint.

8. Parch-foil 1 proved very satisfactory in preventing all types of undesirable surface flavours, but certain other brands were associated with an "objectionable" surface flavour.

9. Avenized parchment, when used with casein-formalin or paraffin treated spruce boxes or with casein-formalin treated poplar boxes, gave excellent protection from the standpoint of preventing undesirable surface flavours, but did not prevent primrose colour.

10. Of the twelve packages tested in the second experiment, the standard package gave the least satisfactory protection against surface flavour defects.

ACKNOWLEDGMENTS

In presenting these results the writers desire to acknowledge the generous assistance and co-operation received from a number of individuals and firms. They are indebted to Dr. C. H. Goulden, Senior Cereal Specialist, Dominion Rust Research Laboratory, for valuable advice in connection with the design of the experiments and the statistical analysis of the data. Through the courtesy of Mr. J. F. Singleton, Associate Director of Marketing Services, Dairy Products Division, Department of Agriculture, Ottawa, Messrs. K. G. MacKay, Senior Dairy Produce Grader for Western Canada, J. A. McManus, Dairy Produce Grader, in charge of

the Winnipeg Office, C. H. P. Killick and L. H. Woodiwiss, Dairy Produce Graders, examined and criticized all of the butter samples. To these experts the writers are especially indebted.

Acknowledgment is also made of the interest and co-operation of the following firms, who supplied box lining materials and boxes: Kilgour's Limited, Winnipeg, Manitoba; Laminated Papers Limited, Montreal, Quebec; Canada Foils Limited, Toronto, Ontario; Kalamazoo Vegetable Parchment Company, Kalamazoo, Michigan; and the Capital City Box Company, Edmonton, Alberta.

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PREDICTION OF MALT EXTRACT OF HYBRID BARLEYS[1]

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[Received for publication July 13, 1942]

In previous papers (3, and others in that series) the relationships between various barley and malt properties were discussed with a view towards simplification of preliminary tests for malting quality. A practical aspect of these studies is that they showed that it was possible to predict certain comparative malting qualities, malt diastatic power and malt extract, of different varieties from barley analyses. Further, the barley analyses require only a small amount of material, and they may be made at an early stage in the production of new varieties. The comprehensive studies were carried out on series of samples representing standard varieties, and it was desirable to confirm the results on samples of hybrids, as it is with hybrid lines that the plant breeders are mainly concerned. The utility of the method for predicting diastatic power has been tested on hybrid material (6) and the utility of the method for predicting malt extract has now been tested in the same way. Determinations of barley extract, requiring only 15 grams barley, were made on 304 samples from the 1940 crop that were submitted for malting tests, and on which malt extract data were available. The results of comparisons between barley and malt extracts are reported herein. As the samples were mainly new hybrids, the investigation may be regarded as a test of the utility of the determination of barley extract for predicting malt extract of new lines that are being produced.

MATERIALS

There were 24 sets of samples from the 1940 crop in this study. Each set, to be known as a station test set from this point on, represents a series of samples grown at a single station. The station test sets are identified in Table 1. The samples represent a few standard varieties and a large number of hybrid lines of varied origin produced by Canadian plant breeders. The hybrids represent a wide choice in parental material and they may be regarded as typical of the barley breeding program at present in progress in Canada.

METHODS

Barley extract was determined by the method previously described (4) involving the use of rapidase and malt diastase. The samples were malted and analysed by the standard procedures used in routine malting tests in this laboratory (1, 2, 5).

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[1] Contribution from the Malting Laboratory, Division of Plant Science, the University of Manitoba, with financial assistance from the National Research Council and the Dominion Department of Agriculture. Published as paper No. 204 of the Associate Committee on Grain Research.

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TABLE 1.—IDENTITY OF STATION TEST SETS AND MEAN VALUES FOR BARLEY EXTRACT AND MALT EXTRACT

No.	Station test set	Number of samples	Barley extract	Malt extract
			%	%
1	Manitoba secondary test	24	70.1	69.7
2	Manitoba standard strains (A)	6	70.9	70.6
3	Manitoba standard strains (B)	6	74.5	74.4
4	Manitoba miscellaneous strains	12	73.6	72.0
5	Manitoba smooth awned strains	12	74.9	72.0
6	Saskatchewan strains (A)	12	76.1	75.2
7	Saskatchewan strains (B)	12	77.0	76.0
8	Saskatchewan strains (C)	12	74.9	74.1
9	Saskatchewan strains (D)	12	74.5	73.7
10	Saskatchewan strains (E)	12	76.6	75.1
11	Saskatchewan strains (F)	12	74.3	73.7
12	Alberta strains (Fallis)	18	79.1	77.4
13	Alberta strains (Edmonton)	18	76.6	75.1
14	Ontario strains A	6	76.0	72.6
15	Ontario strains B	6	76.0	73.6
16	Ontario strains C	6	76.2	72.5
17	Ontario strains D	6	76.5	74.0
18	Brandon strains	24	75.1	72.2
19	Eastern hybrids (A)	12	78.5	76.4
20	Eastern hybrids (B)	6	77.9	75.6
21	Eastern hybrids (C)	7	78.6	75.5
22	Quebec preliminary test (A)	16	76.9	75.9
23	Quebec preliminary test (B)	23	76.2	74.0
24	Quebec preliminary test (C)	24	78.3	75.9
	Total and mean	304	75.8	74.1

RESULTS AND DISCUSSION

Graphical Representation of Results

The data for barley extract and malt extract for the 304 samples are given in Figure 1, as a scatter diagram. The samples that are high in barley extract are also high in malt extract. It is obvious that a close relationship exists between the two properties ($r = .824$) and that the determination of barley extract provides a means of selecting the most promising samples with respect to malt extract.

Following the procedure used in a previous paper (6), the samples are first treated as one test set in order to determine the general efficiency of the prediction method. In Figure 1 a line has been drawn separating from the rest the 30 samples (10% of the total number) highest in barley extract, and another line at right angles to it separates from the rest the 30 samples highest in malt extract. These lines divide the samples into four groups, as follows: Group A, those selected by both methods; Group B, those selected on the basis of barley extract and not on malt extract; Group C, those selected on the basis of malt extract and not on barley extract; Group D, those discarded by both methods.

Group A contains 20 samples and Groups B and C each contain 10 samples. Regarding the samples as one test group, the selection method based on barley extract is therefore 67% efficient. That is, by selecting

the 30 samples highest in barley extract, Groups A and B in Figure 1 would be chosen, but only the 20 samples in Group A would be selected correctly for high malt extract. As was noted in a previous paper on prediction methods (6), the efficiency obtainable by random selection is much lower than the above figure. A random selection of 10% of the samples would contain only 3 rather than 20 of the 30 samples highest in malt extract. The determination of barley extracts of hybrid lines therefore provides a useful method by which to select the most promising lines, even though the general efficiency is only 67%. However, for reasons discussed below, the efficiency rating based on selection over all samples underestimates the utility of the prediction method.

Check samples of O.A.C. 21, which is the standard malting variety in Canada, are always included in sets of hybrid lines under test. Comparisons are made with O.A.C. 21 with respect to barley extract and samples are classed as promising or not promising. Detailed examinations of the data for the individual test sets were made in a similar manner to the treatment of Figure 1 and the results are shown in Table 2. These show that 202 samples are classed as promising and would be retained on the basis of barley extract; of these 202 samples, 81 were not promising with respect to malt extract and would be retained in error. Only 7 samples promising in malt extract would be discarded on the basis of barley extract. This low loss of promising samples may seem somewhat abnormal, but it is due to the fact that O.A.C. 21 modifies very well during malting and produces practically all its potential malt extract. It is, therefore, much more likely that samples producing amounts of barley extract equal to or greater than that of O.A.C. 21 would fail to produce equivalent malt extracts than that the reverse would occur. The error of prediction of malt extract from barley extract results mainly in the retention of less promising lines, which would fail to meet the requirements of advanced tests and would be discarded later. This latter point is discussed later, as is the possible loss of samples promising in malt extract, but lower than the standard in barley extract.

It is standard practice, for obvious practical reasons and for other reasons discussed in previous papers (7, 8), to make comparisons only within station test sets. It is of intererest to note that additional proof for the need for this precaution was obtained in this study. It may be noted in Table 1 that certain pairs of station test sets, for example, sets 5 and 8 and sets 6 and 14, differ but slightly in mean values for barley extract but differ widely in mean values for malt extract. Estimates of malt extract, on the basis of barley extracts, would lead to erroneous selection if comparisons were made between pairs of station test sets, particularly if comparisons were made between sets 3 and 16. From these considerations it is quite evident that, although a general relationship between station test sets exists, it cannot be used satisfactorily to predict comparative malt extracts of sets grown under different conditions, and predictions, therefore, must be made within station test sets.

The limitation, that prediction methods are more reliable within stations than over all stations, is actually mainly of academic interest. No attempts are made to compare varieties or strains unless they are grown

at the same station or same series of stations. It may be concluded that the determination of barley extracts of hybrid lines and comparison of these with the values for comparable samples of O.A.C. 21 provides a basis for the selection of lines that will produce malts satisfactory in extract.

Statistical Analyses

Determinations of correlation and regression coefficients and other statistics were carried out in the same way as for a previous paper (6) and significant correlations within test sets were obtained. These did not provide any additional information except to confirm the conclusions already discussed. While certain interesting information was obtained, it is mainly of academic interest, and its does not appear necessary to include statistical details in this paper.

General Discussion

The determination of barley extract may be made on a 15-gram sample, and the fact that malt extract can be predicted from the results is of definite advantage to the plant breeder. It may be noted at this point that owing to its small size the sample should be fully representative of the strain being tested. As with the prediction of malt diastatic power (6), quality tests may now be made on hybrid lines at a much earlier stage than was possible by use of the malting test. The values for barley extract for new lines are compared with those of comparable samples of O.A.C. 21, and the promising material may be selected. Large populations may be readily reduced and only promising material would be continued in field tests, for increase and for further crossing.

It should be observed again that it is not proposed to substitute barley analyses for the malting tests. Prediction methods have been developed in order to give plant breeders information on the quality of their lines as soon as possible, to save the plant breeder labour, space and money in increasing unsuitable material to the stage where it may be malted, and to reduce the load and expense of the malting laboratory in conducting expensive malting tests on material, the unsuitability of which may be detected readily by rapid, simple tests on the barley. The samples are not selected on the basis of barley extracts alone, but also on the basis of barley diastatic power (6). It has been noted (7) that enzymatic activity also affects comparative yields of malt extract from barley extract, and at least some of the 81 samples in the fourth column in Table 2 would be discarded on the basis of diastatic power. As observed previously, one of the outstanding characteristics of O.A.C. 21 is its ability to convert practically all its potentially soluble material into malt extract, and this ability is a function of its enzymatic activity. Thus, high amounts of barley extract are of no great value without sufficient enzymatic activity to convert them into malt extract.

It should also be noted that the classifications in Table 2 were based on differences from O.A.C. 21 that were significant on the basis of analytical errors. The standard error is 0.2% extract, giving a necessary difference of 0.4% for the 5% level. In practice, the limiting factors in variety evaluation are not analytical errors, but interactions between varieties and

stations. For this reason, when varieties are grown at only one station, samples with differences from O.A.C. 21 of less than 1.5% barley extract are considered to be worth testing further. On this basis, the samples listed in Table 2 as being promising in malt extract, but not promising in barley extract, would be retained. Thus some leeway is permitted in selection for barley extract and the losses of promising material would be small.

TABLE 2.—RESULTS OF SELECTION WITHIN STATION TEST GROUPS

Test group	No. of samples compared with O.A.C. 21	Classed as promising on basis of barley extract, as equal to or higher than O.A.C. 21 in barley extract		Classed as not promising on basis of barley extract, as lower than O.A.C. 21 in barley extract	
		Equal to or higher than O.A.C. 21 in malt extract	Lower than O.A.C. 21 in malt extract	Equal to or higher than O.A.C. 21 in malt extract	Lower than O.A.C. 21 in malt extract
1	23	2	7	0	14
2	5	1	2	0	2
3	5	0	2	0	3
4	11	6	1	3	1
5	11	4	1	1	5
6	11	7	2	0	2
7	11	7	3	1	0
8	11	8	2	0	1
9	11	6	4	0	1
10	11	8	1	1	1
11	11	1	5	0	5
12	17	13	2	0	2
13	17	12	1	0	4
14	5	3	2	0	0
15	5	2	3	0	0
16	5	0	2	0	3
17	5	1	3	0	1
18	23	1	11	0	11
19	11	11	0	0	0
20	5	3	2	0	0
21	6	3	3	0	0
22	15	3	11	0	1
23	22	2	5	1	14
24	23	17	6	0	0
Total	280	121	81	7	71

The elimination of unsuitable material, as shown for barley extract in Figure 1, which is made possible by these simple tests is actually an important step in plant breeding work. It enables the plant breeders to concentrate their efforts on the strains that have promise. When material appears promising by barley analyses, for diastatic power and extract, the plant breeder is advised to grow it under local trials, or regional trials, from which it will be submitted for laboratory malting tests.

SUMMARY

Tests were made on the utility of the barley extract determination as a method for selecting hybrid lines with high yields of malt extract. The

determination of barley extract may be made at a much earlier stage of production than malting tests, as only 15 grams of barley are required. Data for barley extract were obtained on 304 samples from the 1940 crop that were submitted for malting tests. Comparisons were made between barley extract and malt extract by means of scatter diagrams.

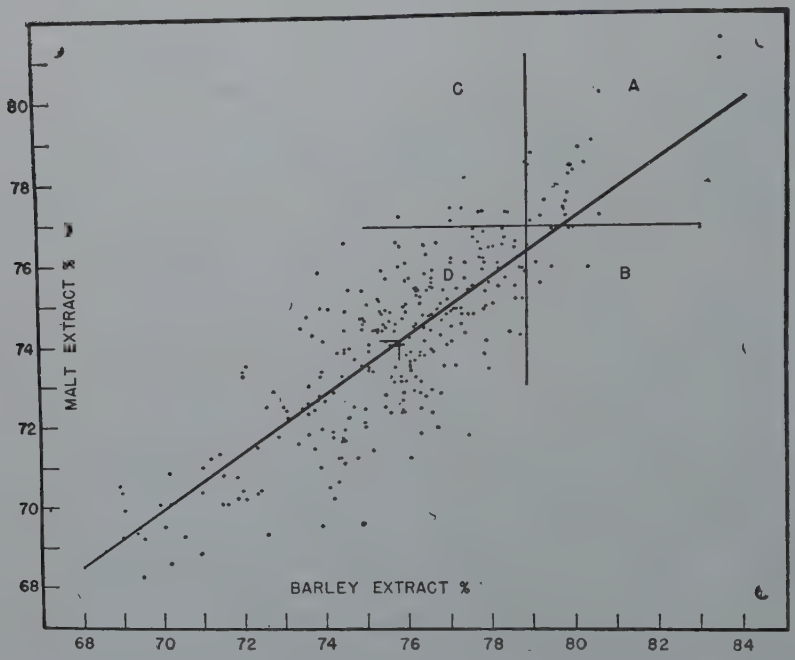

FIGURE 1. Scatter diagram illustrating the relationship over all samples between barley extract and malt extract.

Over all samples, there is a high correlation between the two properties ($r = .824$) and high correlations between varieties were also obtained within stations. The determination of barley extract provides a useful method for selection of lines high in malt extract, particularly when comparisons are made within stations. It is shown that test sets (or stations) producing equal amounts of barley extract do not necessarily produce equal amounts of malt extract. This limitation to the prediction method is not serious, as comparisons are always made within test sets, using the values for check samples of O.A.C. 21 as standards for selection. No comparisons between station test sets are made in practice.

ACKNOWLEDGMENTS

The author is indebted to Dr. J. Ansel Anderson and Dr. H. R. Sallans for their continued interest in this work and to Dr. P. J. Olson in whose department the work was undertaken.

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A NOTE ON THE CHEMICAL COMPOSITION OF MANITOBA SHELLED CORN, 1941 CROP[1]

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[Received for publication August 12, 1942]

Manitoba shelled corn, the production of which has increased rapidly during the last five years, has in the past been used entirely for feeding purposes. However, the possibility of using it in the distilling and starch industries must now be considered owing to the difficulty of importing foreign corn. It was therefore considered timely to publish data on the chemical composition of the 1941 crop of Manitoba corn, and to compare these with corresponding data for Ontario corn and such imported corns as could be obtained. The analyses included moisture, protein, starch, ash, fat, fibre, and carotene. Carotene content was determined principally because feeders have shown interest in the vitamin A potency of Canadian corn, and it has been amply established that this is related to carotene content (1, 2, 3).

Averages of the various Canada Western grades of corn inspected during the period August 1 to December 31, 1941, were available for analysis and corresponding samples of Canada Eastern corn were also obtained. The western corn originates entirely in Manitoba and the eastern corn in Ontario. In addition, 15 samples of foreign corns were collected through the co-operation of some of the starch and distilling companies.

All samples were cleaned free from dockage and analyses of moisture, protein, ash, fat, and fibre were made by the methods of the Association of Official Agricultural Chemists (4). Starch content was determined by the Lintner-Schwartz (5) method as reported by Ayre *et al.* (6), and the carotene content according to the method given by Binnington *et al.* (7). All results were reported on the basis of 13.5% moisture content.

The analytical values obtained on the individual samples are given in Table 1, and are summarized by groups in Table 2. The Western Canadian corn is highest in protein content, averaging 1.7% higher than the South African White and 0.7% to 1.1% higher than the other types. In starch content the Western Canadian corn is about 0.5% lower than that from Eastern Canada and about 2% lower than most of the foreign corns. Compared with South African White it is 3.3% lower. Both Eastern and Western Canadian samples are high in oil content, whereas the South African White and the American Yellow are low. Differences in fibre content are comparatively small. In this connection it may be mentioned that if the dockage were not removed from the Canadian samples the maximum increase in fibre content would be no more than 0.1%. In ash content the Canadian and American corns are very similar; they are somewhat higher than African samples and lower than the Argentine corns. As would be expected, the white corn is very low in carotene content. The Manitoba corn, though lower in this constituent than the Eastern

[1] Published as paper No. 205 of the Associate Committee on Grain Research.
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Canadian and the Argentine samples, is considerably higher than the American and South African Yellow corns.

In considering the data it should be borne in mind that the Canadian samples represent the crop of only one year, and that the foreign corns are represented by very few samples. Accordingly, it is not advisable to generalize concerning the relative quality characteristics of the various types of corn.

TABLE 1.—ANALYSES OF DOCKAGE FREE SAMPLES OF CANADIAN AND FOREIGN CORNS

Description	No. of cars represented	Protein	Starch	Fat	Fibre	Ash	Carotene
		%	%	%	%	%	p.p.m.
Manitoba							
2 C.W. Yellow	32	10.3	59.7	5.5	1.9	1.23	28.3
3 C.W. Yellow	14	10.4	58.9	4.7	1.9	1.25	29.2
4 C.W. Yellow	13	10.3	60.0	5.1	1.9	1.27	27.9
5 C.W. Yellow	4	10.6	59.5	4.9	2.0	1.29	29.8
Ontario							
1 C.E. Yellow	121	9.2	60.1	5.3	2.2	1.21	36.1
2 C.E. Yellow	76	9.1	60.0	4.8	2.1	1.24	35.1
3 C.E. Yellow	11	9.5	61.4	4.4	2.0	1.22	35.5
Argentine Yellow	—	9.7	59.7	4.2	1.7	1.32	37.7
Argentine Yellow	—	9.4	61.1	4.7	1.7	1.37	38.2
Argentine Yellow	—	9.9	62.2	4.2	1.6	1.34	40.0
Argentine Yellow	—	9.2	60.9	4.6	1.8	1.38	25.0
Argentine Yellow	—	9.8	60.8	4.5	1.8	1.40	28.9
South Africa White	—	8.9	63.1	3.5	1.6	0.98	2.7
South Africa White	—	8.6	63.9	3.6	1.7	0.97	2.1
South Africa White	—	8.1	63.8	4.0	1.6	1.05	1.9
South Africa White	—	8.7	61.3	4.0	1.8	1.02	1.7
South Africa Yellow	—	9.2	62.0	4.2	1.8	1.02	13.4
South Africa Yellow	—	9.4	61.6	4.4	1.6	1.01	24.2
America Yellow	—	9.2	61.6	4.2	1.9	1.18	24.6
America Yellow	—	9.2	60.6	3.9	2.0	1.24	17.5
America Yellow	—	9.4	61.2	4.0	1.9	1.22	17.9
America Yellow	—	9.3	63.6	4.0	1.8	1.16	24.8

TABLE 2.—MEAN DATA FOR CANADIAN AND FOREIGN CORNS

Country of Origin	Type	Protein	Starch	Fat	Fibre	Ash	Carotene
		%	%	%	%	%	p.p.m.
Western Canada*	Yellow	10.3	59.6	5.2	1.9	1.25	28.5
Eastern Canada*	Yellow	9.2	60.1	5.1	2.2	1.22	35.7
Argentina	Yellow	9.6	61.0	4.5	1.7	1.36	34.0
South Africa	White	8.6	63.0	3.8	1.7	1.00	2.1
South Africa	Yellow	9.3	61.8	4.3	1.7	1.02	18.8
United States	Yellow	9.6	61.8	4.0	1.9	1.20	21.2

* Canadian data are weighted for numbers of cars in each grade.

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THE RELATIVE IMPORTANCE, FROM THE PATHOLOGICAL STANDPOINT, OF TWO TYPES OF SMUDGE ON WHEAT KERNELS[1]

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[Received for publication July 30, 1942]

The term "smudge" as applied here refers to dark brown discolorations on wheat kernels. It is usually confined to the germ end of the seed but sometimes extends over most of the surface. Other investigators have applied a variety of names such as black-point and kernel smudge to this condition. It is sometimes confused with bacterial black-point, which is caused by *Phytomonas atrofaciens* (MacCull.) Bergey *et al.* In the present investigation two different types of smudge have been differentiated and it seems probable that they may arise from different causes.

A number of plant pathologists have studied wheat seed discolorations and have published the results of their investigations. According to Dastur (2), Passinetti studied a condition in Argentine wheat, which he called black-point, and came to the conclusion that it was entirely physiological. He did not find any organism in the discoloured tissues of the seed and discovered that the germination of the affected seed was as good as that of the normal seed. Dastur studied wheat, produced in India, which showed similar discolorations. He found that it germinated almost as well as healthy seed and that plants grown from it produced normal ears and grain. He also found hyphae in the discoloured tissues and isolated numerous fungi from such seeds on moist filter paper and culture media. They included species of *Alternaria*, *Cladosporium*, *Fusarium* and *Helminthosporium*. Fomin and Nemlienko (3) have recently published the results of their study of smudge of cereals in the Ukraine. They considered that the disease caused considerable non-emergence and seedling blight in that region, and attributed it to *Helminthosporium sativum* P. K. and B., and an undetermined species of *Alternaria*. They concluded that *H. sativum* caused some shrivelling of the kernel and that *Alternaria* sp. did not.

On this continent, the problem of smudge of wheat has been investigated by several research workers. Simmonds (9) in 1928 reported the production of smudge in wheat by means of artificial inoculation with *H. sativum*. The affected kernels showed black discolorations particularly at the germ end. Some of them were more or less bleached and shrunken. He also reported that smudged kernels, selected from a sample of Marquis wheat, weighed much less than clean kernels from the same sample, and that they proved to be decidedly inferior in germination tests in the greenhouse and field. Waldron (11, 12), studied it in North Dakota. He concluded that smudge was attributable almost entirely to *H. sativum* and species of *Alternaria*. He reported that the emergence from affected seed was reduced slightly but that the yield and quality of the grain produced

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from it were equal to those of grain produced from clean seed. Machacek and Greaney (5) concluded that two species of *Alternaria* and two species of *Helminthosporium* were the fungi chiefly associated with smudge in Manitoba. They considered that the species of *Alternaria* did not lower the germination and yield of the affected wheat while the species of *Helminthosporium* did. Simmonds and Mead (10) suggested that smudge should be taken into account when making a visual examination of wheat seed. They considered *H. sativum* and possibly other fungi were the cause of the discoloration. Russell and Ledingham (7) reported that less than 1% of the kernels, in 181 samples of 1939 wheat seed studied by them, were affected by smudge. Mead, Russell and Ledingham (6) reported that approximately 0.7% of the kernels were smudged in 562 samples of 1940 wheat from different parts of Saskatchewan.

MATERIALS AND METHODS

The samples of wheat used in these investigations were drawn mainly from seed sent in by farmers in different parts of Saskatchewan and western Manitoba, but a few samples were produced on experimental plots. All of the samples showed more or less smudge. They were all subjected to an incubation test, and certain ones were given a germination test in soil in the greenhouse or germination and yield tests in the field.

In the incubation tests, 100 seeds of each class were selected from each sample and placed on moist filter paper in Petri dishes; 25 seeds were placed in each dish and they were left to incubate for 4 days at a temperature of 24° C. Ar the end of that period a record was taken of the number and kind of fungous colonies which had developed on the kernels and surrounding paper. Also a record was kept of the number of seeds which failed to germinate or germinated poorly.

The germination tests in the greenhouse were conducted in field soil in 6-inch flower pots. Usually 300 seeds of each category were sown at the rate of 50 per pot in 6 replicates. The records were taken within 12 days of the time of planting. The average temperature in the greenhouse during these tests was about 20° C. The field tests were arranged in 8-foot rows with 100 seeds in each row. These single-row plots were replicated and randomized according to accepted field plot technique.

RESULTS OF INCUBATION TESTS

At the beginning of this investigation 42 samples of seed wheat produced in 1940 were examined, and two classes of seed were picked from each. One class exhibited smudge while the other appeared to be clean and healthy. The object of this test was to compare the fungous flora of the two classes and to see if any correlation existed between certain fungi and the presence of smudge on wheat seed. Also the relation of certain fungi and poor germination was considered. A summary of the data secured is shown in Table 1. The number of colonies of *H. sativum* and *Alternaria* spp. was kept separate but the other fungi which appeared were all recorded together. These included *Cladosporium herbarum*, *Nigrospora sphaerica*, *Fusarium* spp., *Penicillium* spp., and a number of others whose identity was unknown. Of all the fungi recorded *H. sativum* appeared to be the only one strongly parasitic to the young seedlings, excepting an occasional *Fusarium*.

TABLE 1.—A COMPARISON OF THE FUNGOUS FLORA AND GERMINATIVE VIGOUR OF CLEAN AND SMUDGED WHEAT KERNELS FROM THE SAME SAMPLES

Class of seeds	Fungous flora			Abnormal germination		Percentage of dead seeds and weak seedlings bearing *H. sativum*
	H. sativum	*Alternaria* spp.	Miscellaneous fungi	Non-germination	Weak germination	
	%	%	%	%	%	%
Clean	1.5	54.0	22.3	4.2	11.4	4.2
Smudged	6.0	76.7	12.5	5.2	14.3	22.1

The results of the incubation test indicated that there was more *H. sativum* carried on the smudged seeds than on the clean ones—6% as compared with 1.5%. However, only a small percentage of the discoloured kernels produced *H. sativum*, therefore much of the discoloration on the kernels must have been caused by something else. It appeared as though *Alternaria* spp. may have been responsible for some of it as the smudged seed bore *Alternaria* colonies on 77% of the kernels, while only 54% of the clean kernels bore this fungus. About 20% of the smudged seeds which germinated poorly, or failed to germinate at all, produced colonies of *H. sativum*. A high percentage of the *H. sativum* colonies occurred on such seeds, but a much smaller proportion appeared on seeds which developed normal seedlings. Commonly the fungus produced brown lesions on the roots and coleoptiles of the diseased seedlings.

In a few of the 1940 seed samples it was noticed that there were two types of smudge present. For reasons which will appear later these are called the mild type of smudge and the severe type of smudge. These are somewhat similar in appearance but certain differences are apparent (Plate 1, bottom). In the mild type the discoloration centres on the embryo and does not appear on the ventral side of the seed, while in the severe type the discoloration does not extend so far from the tip of the kernel where it appears on the ventral side as well as the dorsal side. On the whole the colour is slightly darker in the severe type. Kernels affected with the mild type are well filled while those affected with the severe type are usually somewhat shrunken and may be noticeably bleached. The first type was seen on approximately ten times as many kernels as was the second type in the samples examined.

Having discovered that these two types of smudge exist in the wheat seed of this area, about 30 samples of 1940 wheat were used to investigate the relative importance of these discolorations from the plant pathological standpoint. In addition to a number of experimental field plot samples, 26 samples were secured from a commercial laboratory where seed grain is tested for farmers. The wheat came from various parts of Saskatchewan and western Manitoba. The samples were selected because they contained both types of smudge. One hundred seeds showing the mild type of smudge were selected from each sample, whenever possible, but in a few cases a lesser number had to be used. An equal number of clean, healthy-looking

seeds were taken as a check. In addition all of the seeds exhibiting the severe type of smudge, which were found while picking out the other type, were placed in a third class. A fourth class received all the seeds which did not exhibit the symptoms of either the mild or the severe type of smudge, but were discoloured in one way or another. All four classes were subjected to the incubation test with the results shown in Table 2.

TABLE 2.—A COMPARISON OF THE FUNGOUS FLORA AND GERMINATIVE VIGOUR OF FOUR CLASSES OF WHEAT KERNELS SELECTED FROM THE SAME SAMPLES

Class of seeds	Number of seeds tested	Fungous colonies			Germination		Percentage of *H. sativum* colonies on dead seeds or weak seedlings	Percentage of dead seeds and weak seedlings bearing *H. sativum*
		H. sativum	*Alternaria* spp.	Miscellaneous fungi	Non-germination	Weak germination		
		%	%	%	%	%	%	%
Clean	2190	1.2	81.0	8.7	3.0	17.1	59.3	3.6
Mild smudge	2190	5.2	88.0	5.8	2.6	19.7	77.9	18.0
Severe smudge	187	84.5	13.4	6.4	20.8	54.5	81.6	91.5
Doubtful	255	41.2	45.5	10.2	15.3	31.8	70.5	61.7

The figures in Table 2 throw considerable light upon the relative value of wheat seeds of the four different classes. It can be seen that clean seeds and those showing the mild type of smudge carried relatively little *H. sativum*, although the latter had more than the former. In each of these two classes about the same number of seeds failed to germinate, and about the same number produced weak seedlings. The class showing the severe type germinated very poorly and produced *H. sativum* on a high percentage of the kernels. Most of the seeds which failed to germinate and most of the weak seedlings in this class were infected with *H. sativum*. It is interesting to note that only 59.3% of the *H. sativum* colonies which did appear on the clean class developed on dead seeds or weak seedlings, while 77.9% of those appearing in the mild smudge class and 81.6% of those appearing in the severe smudge class were on seeds which did not germinate normally. On the kernels showing smudge, *H. sativum* frequently covered the whole surface, to the complete exclusion of other kinds of fungi (Plate 1, top). The performance of the seeds of the doubtful class was intermediate in most respects between that of the mild smudge and that of the severe smudge classes.

RESULTS OF GERMINATION TESTS IN THE GREENHOUSE

The first of these tests was conducted before it was realized that there were the two distinct types of smudge. Consequently only two classes of seed were used—those which appeared to be clean and healthy, and those which exhibited smudge. Three hundred seeds of each class were used. The results are given in Table 3. In this test, surprisingly enough, the discoloured seed excelled the clean seed in several respects, including total germination and dry weight of seedlings at the end of the test. Apparently most of the smudge was of the mild type and the seeds probably were slightly heavier than the clean ones.

PLATE 1. Top: Wheat seed, from incubation test, covered with *H. sativum* fruiting. Stub of first seminal root evident on the left.

Bottom: Six grains of wheat illustrating the dorsal and ventral aspects of kernels of the following classes: left, clean; centre, mild type of smudge; right, severe type of smudge.

TABLE 3.—THE RELATIVE GERMINATIVE VIGOUR OF CLEAN SEED AND SEED SHOWING SMUDGE

Class of seeds	Emergence				Disease symptoms			Dry weight of seedlings
	Normal*	Delayed*	Distorted*	Total	Pre-emergence blight	Non-germination	Lesions	
	%	%	%	%	%	%	%	gm.
Clean	74.4	7.6	2.4	84.4	11.0	4.6	2.6	1.084
Smudge	79.4	5.0	2.6	87.0	7.0	6.0	3.6	1.142

* The meaning of these terms is given in a previous article, Russell and Ledingham (7).

In the second test three classes of seed were used from two different varieties of wheat. One class contained seeds exhibiting the mild type of smudge, another class contained seeds of the severe type, while the remaining class consisted of clean healthy-looking seeds. The results are shown in Table 4.

TABLE 4.—THE RELATIVE GERMINATIVE VIGOUR OF THREE CLASSES OF SEED FROM BOTH APEX AND REGENT WHEAT

Class of seeds	Variety	Weight of seed	Emergence		Disease		Dry weight of seedlings
			Normal	Total	Pre-emergence blight	Lesions	
		gm.	%	%	%	%	gm.
Clean	Apex	11.575	70.4	93.4	5.4	1.6	1.224
Mild smudge	Apex	11.017	84.4	94.6	3.6	1.4	1.344
Severe smudge	Apex	10.124	56.4	82.0	16.0	15.0	1.032
Clean	Regent	12.046	68.0	92.0	4.4	2.0	1.026
Mild smudge	Regent	11.512	63.6	87.4	7.6	3.6	1.036
Severe smudge	Regent	10.061	41.4	74.6	16.4	11.0	0.822

From the results of this test we are able to study separately the behaviour of the seed affected by the two different types of smudge. In the third column of Table 4 the weight of 300 selected seeds is given in each case. The clean seeds were the heaviest, the mild type seeds were somewhat lighter, and the severe type seeds were considerably lighter. In total emergence the clean class was best in the Regent and the mild smudge class in the Apex, while the severe smudge class was decidedly the poorest in both varieties. Also the latter class showed much more pre-emergence blight and more lesions on the seedlings. The dry weight of the seedlings produced from seeds showing the severe smudge was about 20% less than that of the seedlings produced from the clean seeds. It seems highly probable that the poor showing of the seeds of the severe smudge class in this test was due to the parasitic action of *H. sativum*.

Next an experiment was conducted to see if seedling blight, arising from smudge of the severe type, could be controlled by treating the seed with ceresan. For this test 1800 seeds were selected from a sample of

Apex wheat grown on experimental plots at Indian Head in 1941. Seeds belonging to the three different classes were sown and one-half of each class was treated with ceresan. The weight of 600 seeds in each case was as follows: clean, 22.64 grams; mild type of smudge, 22.43 grams; and severe type, 19.87 grams. The results of the test are given in Table 5.

TABLE 5.—THE EFFECT OF TREATMENT WITH CERESAN ON THE GERMINATION OF SEED OF THE CLEAN, MILD SMUDGE AND SEVERE SMUDGE CLASSES

Class of seeds	Treatment	Emergence		Disease		Yield; dry weight
		Normal	Total	Pre-emergence blight	Lesions	
		%	%	%	%	gm.
Clean	Untreated	73.3	91.3	6.3	6.7	3.475
Clean	Ceresan	96.3	99.7	0.0	2.7	4.345
Mild smudge	Untreated	78.3	92.0	5.7	4.7	3.625
Mild smudge	Ceresan	93.0	97.3	2.3	1.3	4.235
Severe smudge	Untreated	51.0	65.3	22.0	26.7	2.650
Severe smudge	Ceresan	95.0	99.0	0.3	1.0	4.005

The figures contained in Table 5 show that ceresan improved remarkably the performance of the seed affected with the severe type of smudge. Total emergence was increased from 65% to 99% and pre-emergence blight was reduced from 22% to 0.3% by the treatment. Moreover the number of seedlings showing lesions was reduced from 26.7% to 1% and the dry weight of the seedlings was increased from 2.6 to 4 grams. Evidently the activities of the parasite were greatly restricted by the seed treatment.

A fourth test was conducted in the greenhouse to see if any evidence would appear of smudge developing in grain produced by plants arising from seed that exhibited either type of smudge. Since the plants were to be grown to maturity in this test, they were sown in 1-gallon, glazed, earthen-ware crocks and only 10 seeds were sown per crock. The three types of seed were selected from a sample of Apex wheat. There were 100 seeds of each type, giving 10 replications. Water was given at regular intervals by placing the crocks on the scales and adding enough to bring all the crocks to a uniform weight. In the seedling stage the wheat was given an abundance of water, but in the flowering and heading stages it probably did not receive enough. The results are summarized in Table 6.

TABLE 6.—THE INFLUENCE OF SMUDGE ON EMERGENCE AND ON THE AMOUNT AND QUALITY OF THE GRAIN

Class of seeds	Weight of seeds	Total emergence	Yield of grain		*Disease rating at maturity
			Amount	Quality	
	gm.	%	gm.		%
Clean	3.79	98	53.86	Good	31.1
Mild smudge	3.73	91	48.12	Good	27.6
Severe smudge	3.40	66	56.34	Good	27.3

* This refers to the amount of common rootrot present on the plants at maturity.

In the above test the emergence of the seed in the mild smudge class was somewhat lower than that of the seed in the clean class, while that of the severely smudged seed was 32% lower than the check. After the seedling stage, however, the survivors in the crocks sown with severely smudged seed recovered so well that at harvest time they excelled the others in yield of grain and condition as regards common rootrot. No smudge was evident in the grain from either clean or smudged seed. The unexpectedly good showing of the plants from the severely smudged seed in the matter of final yield and condition was probably due to the fact that insufficient water was given to allow proper development of the more numerous plants in the other classes.

RESULTS OF FIELD TESTS

In the spring of 1941, smudged seed together with an equal amount of clean seed from 4 different samples was sown in the field. Enough of it was available to sow 10 rows of each. One-half of each type of seed was sown without treatment and the remainder was treated with ceresan. The results of this test, as far as emergence is concerned, are given in Table 7, but yield data were not secured as many of the rows were partially destroyed by mice just before harvest time.

TABLE 7.—EMERGENCE NOTES ON CLEAN AND SMUDGED SEED, BOTH TREATED AND UNTREATED

Class of seeds	Treatment	Average emergence of five replicates				Average emergence of samples
		Sample 1	Sample 2	Sample 3	Sample 4	
		%	%	%	%	%
Clean	Untreated	73	75	75	60	70.7
Clean	Ceresan	79	71	71	71	73.0
Smudge	Untreated	77	73	75	68	73.2
Smudge	Ceresan	79	75	82	70	76.5

The results of this test indicated that seeds affected with smudge, provided it was of the mild type, could give as good or better germination than clean seed from the same samples. On the average, ceresan improved the germination slightly. The rows were harvested and examined for smudge. Very little was present but there was as much of it in the grain from the clean seed as there was in that from the smudged seed.

TABLE 8.—THE RELATIVE GERMINATIVE VIGOUR OF THE THREE CLASSES OF SEED AND THEIR YIELDS OF GRAIN UNDER FIELD CONDITIONS

Class of seeds	Average emergence of five replicates			Average emergence of samples	Average yield of five replicates			Average yield of samples
	Sample 1	Sample 2	Sample 3		Sample 1	Sample 2	Sample 3	
	%	%	%	%	gm.	gm.	gm.	gm.
Clean	95.2	94.0	86.5	92.3	209.6	210.0	252.2	223.9
Mild smudge	95.4	88.8	70.2	85.6	203.0	209.0	253.7	221.9
Severe smudge	72.6	80.0	36.2	64.9	172.8	186.0	160.7	173.2

In 1942, seeds of the three classes were sown in the field. Fifteen hundred were selected from each of three different samples. The seeds were sown about May 20, after the soil had become sufficiently warm to favour the activity of *H. sativum* in the soil. The emergence counts and yields are summarized in Table 8.

In this test the performance of the different classes of seed varied with the sample. An examination of the results of the incubation tests of these three samples showed that sample 1 carried the least *H. sativum* and sample 3 carried the most. Seeds having the mild type of smudge germinated as well as the clean seed in sample 1, but did not do as well in the other two. Seeds having the severe type of smudge proved decidedly inferior to the other two classes in each case but the difference was most pronounced in sample 3 which was produced in western Manitoba.

In the matter of yields, the clean seed and seed of the mild smudge class were of about equal value while the seed of the severe smudge class proved to be decidedly inferior. The crop from it was about 23% less than that from each of the other classes of seed. In the individual samples, there was a distinct correlation between the amount of *H. sativum* present in the seed and the reduction in yield.

DISCUSSION

Smudge of wheat is of some economic importance in the Prairie Provinces of Canada. Conners (1) reported that 76 cars out of one thousand, from different points in Manitoba, inspected at Winnipeg during September, 1940, were degraded on account of smudge. During the same time 24 out of 1000 cars from Saskatchewan and 2 from Alberta were degraded for the same reason. Our own records (6, 7) show that it is present in many of the seed lots sown by the farmers of Saskatchewan. It is important that we should know what effect smudge has on the value of wheat for seed purposes and also on its milling and baking qualities. The present paper throws some light on the former problem.

One of the main points to be settled with respect to smudge is its effect upon germination. This will depend partly upon whether or not the affected kernels carry fungi which are parasitic to the young seedlings. In Saskatchewan, seed exhibiting the mild type of smudge, like the Argentine wheat studied by Passinetti, appears to be almost devoid of parasitic fungi and germinates as well as clean seed. Whether the discoloration in such cases arises from purely physiological causes, or not, has not been determined. Frequently, but not always, such seed produces more colonies of *Alternaria* spp. in incubation tests than does clean seed from the same samples. However, the rôle of *Alternaria* in the production of smudge symptoms is not clear. Machacek and Greaney (5) stated that two species of *Alternaria* were associated with it and they referred to the *Alternaria* type of smudge. Fomin and Nemlienko (3) believed that some of the smudge on wheat and barley in the Ukraine was caused by an undetermined species of *Alternaria*. Various other workers have reported isolating *Alternaria* from discoloured kernels, but none of the investigators have published conclusive data to show that an *Alternaria* can produce the symptoms of smudge on wheat—Henry (4) reported negative results. Sallans (8) reported negative results in field tests with Marquis wheat, but the results of his greenhouse tests

suggested that *Alternaria* sp. might produce some seed discoloration under favourable conditions. In the incubation tests, summarized in Tables 1 and 2, *Alternaria* has been more plentiful on the average on seed showing smudge of the mild type than on clean seed. In some samples, however, it was equally plentiful on both clean and smudged kernels.

The seed exhibiting the severe type of smudge in this region is infected to a large extent with *H. sativum*. This is clearly shown by the incubation tests recorded in Table 2. The same seed showed relatively little *Alternaria;* probably because the latter fungus was crowded out in most cases by the growth of *H. sativum* on the seed. Such seed germinated poorly, not only in Petri dishes on moist filter paper, but also in soil in the greenhouse and in the field. As shown in Table 8, the use of such seed may result in lower yields under field conditions. Moreover, many of the seedlings showed distinct symptoms of seedling blight. Most investigators are agreed in assigning an important rôle to *H. sativum* in the production of smudge.

The studies described in this paper have a direct and practical application to the testing of seed wheat. The two types of smudge can be recognized by visual examination. The mild type is of little significance, while the severe type is a reliable indication of the presence of *H. sativum*, and grain showing appreciable amounts of it should not be used for seed, unless it is treated with a suitable fungicide such as ceresan. Fortunately this type of smudge has rarely been found in appreciable amounts in this province. Discolorations, other than the two types of smudge described herein, are met occasionally in the wheat of this region. The results given in Table 2 indicate that some of them are associated with *H. sativum* while others are not. Taken together they affect a very small proportion of the kernels in the seed grain of this province.

Few investigators have attempted to separate different types of smudge, and Machacek and Greaney stated that they could not, by visual examination of the seed distinguish the *Alternaria* type of smudge from that caused by *Helminthosporium*. Dastur (2) recognized that some of the smudged kernels in the Indian wheat, with which he worked, were free from parasitic bacteria and fungi; but he found it impossible to say, from the external symptoms, which of the black-point seeds had organisms in them. With the recognition of the mild and severe types, described in this paper, it becomes clear that the behaviour of a smudged seed sample will depend largely upon how much of each type is present in it.

In connection with the symptoms of severe smudge on the grain, it is interesting to note that Dastur in his histological studies found the mycelium, in the coats of affected seed, to be most abundant in the funicle and in the pericarp in the central region of the furrow on the ventral side of the seed. He also states that the darkest part of the black-point seed is the part of the furrow near the funicle. It has already been pointed out that this part is discoloured in the severe type of smudge but not in the other, in this province.

Several investigators have compared the size of smudged and clean kernels from the same samples. Simmonds (9) found that smudged seeds were much lighter than clean ones. Waldron (11) reported that black-point kernels in his tests proved to be definitely heavier than the kernels

showing no evidences of infection. He ascribed this partly to a stimulation of the development of the endosperm following the entrance of the fungus into the developing ovule. Machacek and Greaney (5) found that the largest kernels were frequently infected and the small shrunken ones were usually free from the disease. They thought that this was because the large kernels forced open their covering glumes and admitted air-borne spores to the developing grain. Of the three classes of seed selected in the present investigation, the clean class has proved to be the heaviest, the mild smudge class was slightly lighter, and the severe smudge class was from 10% to 15% lighter than the clean. This indicates that the fungus had infected the kernels early enough and had penetrated deeply enough to interfere with the flow of nutrients to the developing seeds. Of course, these were selected seeds and not random samples, but it was evident, from a visual examination, that the seeds exhibiting the severe type of smudge were not as plump, on the average, as the seeds of the other two classes.

The treatment of seed wheat with ceresan or similar dust fungicides seems promising as a means of controlling seedling injury arising from the severe type of smudge. Although Waldron (12) reports no control by this method, Machacek and Greaney (5) state that they found the emergence from seed naturally infected with *H. sativum* was always improved by seed disinfection, and, with few exceptions, treatment of diseased seed reduced the amount of root rot and increased the yield of grain. The results reported in Table 7 of this paper show a slight improvement in emergence through the use of ceresan in a field experiment with seeds affected mainly with mild smudge, and those reported in Table 5 show a remarkable improvement, under greenhouse conditions, in the performance of seeds exhibiting the severe type of smudge. It seems reasonable to suppose that the presence of the fungicide on the seed in the soil would suppress the development of the fungus from the seed coat and allow the seedling to develop with less hindrance from infection from that source.

It was not considered likely that the mycelium of *H. sativum* is ever systemic in the wheat plant. Therefore it was not expected that the sowing of seeds affected with the severe type of smudge would result in the production of smudged seed. Nevertheless, the experiment summarized in Table 6 was conducted to secure data relating to this point. Apparently the effect of seed-borne infection was not operative much beyond the seedling stage.

SUMMARY

Two types of smudge on wheat kernels are described. These can be distinguished by visual examination. The results of certain tests and experiments are presented to show that one type is relatively unimportant, from the pathological standpoint, while the other indicates the presence of *H. sativum*, a vigorous parasite of wheat seedlings. These particular kinds of wheat seed discolorations are referred to as the mild type of smudge and the severe type of smudge respectively. From the results of this investigation it is estimated that approximately nine-tenths of the smudge which occurs in wheat in Saskatchewan is of the mild type.

Remarkably good control of seedling blight was obtained by treating seed showing the severe type of smudge, with ceresan.

No evidence was seen which would indicate that smudge resulted in the mature crop from the sowing of seed which exhibited smudge of either type.

ACKNOWLEDGMENTS

The author wishes to acknowledge the co-operation of the Associated Laboratory Services of Saskatoon in supplying the majority of the seed samples used in this investigation.

He is also indebted to Dr. P. M. Simmonds for helpful suggestions and criticism during the course of the investigation.

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BOOK REVIEW

THE TAKE-ALL DISEASE OF CEREALS. S. D. Garrett. Technical Communication No. 41. Imperial Bureau of Soil Science, Harpenden, England. 1942. 2s. 6d.

Contributions on take-all, a disease which can be so destructive in wheat crops, are always of interest to pathologists and others interested in wheat production. In this communication, the author reviews the pertinent literature rather fully with justifiable emphasis on soil factors in relation to etiology. His recent work and interpretations on this relationship, which are widely recognized as valuable additions to our knowledge of the subject, are analyzed here in some detail.

The dissertation is not long, containing only 37 pages and 1 plate of 6 illustrations, yet it is comprehensive. There are nine subheadings: Introduction, Symptoms and Diagnosis, Physiology and Morphology of *Ophiobolus graminis*, Pathogenicity, Field Observations and Prevalence, The Life-cycle, Origin and Dispersal of the Disease, Interpretation of Pot Experiments and Control. The reviewer would liked to have seen more data on the economic importance of the disease, especially in regard to the increased wheat acreage in Britain. The section on pathological histology is well summarized. In reviewing pathogenicity studies, including work conducted in Canada, the author writes in part as follows: "The wide host range of *O. graminis* on cereals and grasses suggests that the search for a variety of wheat resistant to the disease is unlikely to be successful." A further difficulty encountered in pathogenicity tests was the great variation in virulence shown by different isolates. Other conditions or factors discussed by the author relating to disease manifestation are soil type, treatment, and soil reaction, and rainfall. The Garrett hypothesis on the influence of aeration in the advance of runner hyphae along wheat roots is fully discussed, as well as the role played by aeration and nutrients on the survival of the fungus in infected plant tissues in the soil. Control of the disease by crop rotation and soil management is considered in the light of recent findings.

The bibliography contains 135 references.

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